CEP
CHEMICAL ENGINEERING PROGRESS

OCTOBER 1958

what's newest in HEAT TRANSFER

CEP exclusive

13 reports on developments important to the designer and operator of heat transfer equipment

Vortex flow for higher heat fluxes....page 68

PLUS: Solvent extraction in metal refining ... Refinery simulation by computer ... Safety factors in air plant design ... Boron hydrides ... Industrial TV ... Final program for Cincinnati ... Plant construction cost reduction.

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CHEMICAL ENGINEERING PROGRESS
October 1958 — Volume 54, No. 10

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CEP . . . . in this issue

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departmental features

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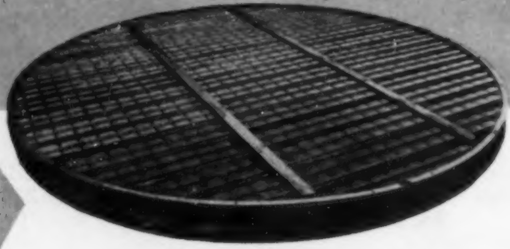

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(Continued from page 3)

departmental features

Quality must come first

L. A. DuBridge, *California Institute of Technology*

It is a basic tenet of democracy that when all of its people do have maximum opportunity to develop their intellectual talents then those people will, of their own free wills, work to make a nation that is strong and fine.

There are of course other nations in the world which do not follow this philosophy of education. There are nations which have adopted the theory that the sole purpose of the educational system is to serve the needs of the state. Under such a system they may offer handsome incentives and handsome opportunities to those particular students who have the type of talents and interests the state may at the moment decide it needs. Such a state of course feels no obligation to those whose talents or interests may lie in other fields.

No one can deny that from the point of view of the state such a system has a certain terrible efficiency. No effort is wasted on "unnecessary" subjects or on "unnecessary" students, i.e., students who do not show the desired degree of competence or enthusiasm. By concentrating its efforts in certain areas such a state can make itself strong in those areas—provided only it has the foresight to predict properly its *future* needs and make adequate provision in the schools for meeting them.

Now there is no use denying the fact that the success of the Soviet Union in building an educational system which greatly strengthens the state has led many Americans to conclude we must adopt a similar policy in order to maintain adequate competitive strength—in particular, adequate military and technological strength. And we dare not dodge this important issue: shall we abandon our goal of providing opportunity to all in order to concentrate our efforts on more intensive training of a few? Shall we re-orient our schools, turning them away from primary attention to the individual, focussing their efforts on the welfare of the nation? Is it true, as some are saying, that we must do this to survive?

I should like to assert that our survival can be assured without altering the purpose of our educational system, but by improving its quality and improving our utilization of the sharpened talents which a better system will provide. I would even go further and say that if we do not maintain the present purpose of our system we might find ourselves struggling to insure the survival of the kind of nation which we do not want—which indeed is not worthy of survival.

If these axioms be true—and I think before this audience I need not try to defend them—then our task is the straightforward one of asking (1) how we can improve the quality of a school system whose objectives are sound and (2) how we can then mobilize the trained talents of our people to insure our nation's strength.

The two questions are not unrelated. For if we, as a nation, find ways of more effectively utilizing the talents of our people, then it will become more obvious to all people that the full development of their talents is a desirable objective—and they will demand high-quality education.

I think that it is clear we are not at the present time utilizing the intellectual talents of our people as effectively as we could. We seem to utilize our physical talents more effectively. If a man has the physique to be a good football or baseball player or boxer or wrestler he can put those talents to good use and can be handsomely rewarded—both financially and by public acclaim. If a woman has physical beauty then her talents too will get plenty of attention and reward. But can we truthfully tell the high-school girl that she will profit as much from being smart as from being beautiful? Does the average high-school boy even believe that it pays to be smart? In fact, does it pay to be smart?

There are of course other compensations in life more important than money. But in a capitalistic society it seems odd that we should withhold financial rewards from those whose talents are as essential to its survival as those of the scientist, the engineer and the teacher. Two economists recently wrote a book which purported to prove, on the basis of the law of supply and demand, that since engineering salaries were less than those of other occupations that therefore there *couldn't* be any shortage of engineers! You and I know that the real reason for lower salaries is that engineers like their work so well they won't leave it even if they don't get such a high salary. But how would you explain to a Russian, for example, the fact that we pay engineers and teachers less than baseball players?

I need not belabor the point. It is obviously desperately necessary that government, industry and the universities provide more adequate compensation for all levels of intellectual talents—and also to make sure that each individual is employed in such a position that his talents are fully used. Then will the incentives, and hence the demand, for quality in educational experience become more real and more impelling. . .

Basically to achieve higher quality in our educational system only three things are necessary:

1. That our teachers be prepared to offer a higher quality challenge, and be prepared to demand a higher quality achievement by the student;
2. That the student be prepared to seek higher quality achievement and to take pride in it; and
3. That parents and citizens understand that the purpose of schools and colleges must be to demand of every student the best that is in him.

In principle of course these are simple and obvious goals. In practice they involve one of the most difficult of all tasks—the changing of the habitual attitudes of the American people. And because the task is difficult many had given up hope of achieving it, had become resigned to the fact that American schools and even many American colleges were bound to be mediocre—because the American people want **them to be mediocre.**

But two fortunate things have happened to give hope that American attitudes can change, and *are* changing. First, a recession has come —suggesting that easy and automatic prosperity for everyone, no matter how dumb, is not necessarily a permanent and automatic property of the American system. Second, Sputnik has come, revealing, what we should have known before, that the Soviet Union is far more advanced technologically, and hence far more dangerous, than we had supposed . . .

It seems evident to me that parents, students, teachers and citizens are now asking questions that are long overdue about whether our educational system is bringing out our best

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talents. Have solid intellectual subjects been buried under a mass of trivia? Have extra-curricular activities crowded out the study periods and the home work? Have the excessive requirements for methodology courses in teacher training curricula left our teachers with no knowledge of the subject they are supposed to teach?

I personally do not believe that Sputnik in itself proved anything one way or the other about our educational system. But I rejoice in the fact that the shock of Sputnik has made many Americans look at these questions more seriously . . .

There is one obvious thing we might try; namely, to make clear to our children and their teachers that we expect the same sort of attention and effort to be expended on the youngsters who wish to be students as on those who wish to be athletes. Every member of a football squad knows he won't make the team if he doesn't work and work hard. Every coach knows that muscles cannot be toughened unless they are used—and used hard. Intellectual muscles need toughening too. Unless they are used they get flabby. . . .

Is it possible to achieve this toughening up process in our public schools? The answer, of course, is that it is possible but not easy. A thirty year trend must be reversed and that is never easy. But as I have said, the signs of a new concern are now abroad in the land and if many people keep pounding away on the subject at all levels, the results will soon become visible.

The question often arises as to what the Federal Government should or could do about improving our educational system. This is obviously a ticklish subject and one on which the American people as a whole have clearly not made up their minds. Nor do I wish tonight to get involved in the intricate questions of local versus federal control of our schools. But the achievement of high quality in our educational system from top to bottom and from Maine to California is clearly of such great national importance that it is appropriate that the federal government assume a certain degree of leadership in this field. How can this be done without interfering with the local autonomy of our schools which is so precious? I can suggest several measures:

1. Administrative and congressional leaders can, in their many public statements give increased emphasis to the importance of education to the national welfare and the importance of greatly improved quality of performance—better teaching and better learning.

2. The scholarship program now being debated by Congress could be used as an important national instrument for increasing the incentives for better quality work. The issue in the scholarship proposals is not whether we should have 10,000 or 25,000 or 40,000 awards. Any one of these is a small number compared to the many young people graduating from high school each year. The question is are these awards going to be treated as prizes for high achievement or simply as charitable gifts to the needy? Are the scholarships created for the purpose of training more scientists and engineers — thus making the social scientists and humanists mad, or are they intended to reward intellectual ability and achievement wherever it may be found? A great opportunity is at hand, if we do not muff it, of making it clear in every school in the land that the nation believes in the importance of intellectual achievement and is willing to reward it. Already the National Merit Scholarships have made a significant contribution in this direction, and for the next year some 480,000 students are competing for 1,000 awards. A federal system of achievement prizes could have a profound effect on student attitudes as well as on parent and teacher attitudes throughout the country.

3. Although these scholarships will be presumably allocated among, and awarded by, the several states, the federal government can help set standards of achievement, can develop suitable achievement tests, can help the states and communities compare the quality of their students with that of students elsewhere, thus engendering a healthy national contest for improving quality—by whatever means the local community selects and can afford. Already in the award of graduate fellowships in science, the National Science Foundation has helped create national standards by which the quality of prospective graduate students can be judged.

Improving our educational system is not a hopeless task. It can be achieved, step by step, if we all believe that improving it is necessary.

Taken from address given at A.I.Ch.E. Golden Jubilee Meeting, Philadelphia, Pa., June 23, 1958.

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The right kind of education

I have touched lightly and briefly on several areas of the Navy's problems and interest. Before closing I would like to make a remark or two, in very general terms, about a very important need for the future.

Our military and naval problems, whether concerned with nuclear weapons, nuclear propulsion, supersonic aircraft, space projects and so on, seem always to lead to increased complexity. We must find ways to keep pace with the swift changes which science and technology are causing. If possible it would be nice to find some way to retard or reverse this trend, but I do not foresee that it will be possible. These complex instruments and the complex procedures necessary for their control and use, must be designed, maintained and operated and commanded by men. The only way we can insure that our men can do this is through education. Probably our biggest problem is that of educating people to cope with the complexities of the future. Since the day Sputnik I entered its orbit, we have heard a great deal about our scientific educational problem, and no one can deny that this must be greatly emphasized. But we must also recognize that there is another important side to this matter which has not been talked about very much; and this is the fact that the products made possible by science are requiring an ever-increasing level of education in all levels of military operation. Right now we are finding that it is most difficult to select, train, use and retain the military personnel to operate our new devices. We find that almost as soon as they are trained, which takes a long time, these people become prime targets for recruitment by higher paying industry. All the trends are toward an aggravation of the situation, because civilian life is becoming more automated every day, just as the military. Young people who are called into our armed forces must be quickly and efficiently trained. To be prepared for this, their basic education must be adequate. It should be well balanced among the various basic disciplines, such as mathematics, physics, chemistry, geography, biology, and so forth. Our youngsters should at least understand that these subjects exist, and have a grounding in the nomenclature.

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We find it increasingly difficult to make a super-sonic pilot who can safely and effectively guide a multi-million dollar war machine, out of the young man who has majored in animal husbandry or physical education and who isn't certain when Newton's Laws were passed. What we need is education for *doing*, not education for living. I urge that you take cognizance of the importance of education in your deliberations here. We do not necessarily need more education, but we do need the right kind of education.

From an address by Vice Admiral R. B. Pirie, Deputy Chief of Naval Operations for Air, at the A.I.Ch.E. Golden Jubilee Meeting in Philadelphia.

We Mean You

Training a supply of responsible managers of a scientific and technological society is a larger task than training an adequate supply of scientists to operate it. The new technological society carries with it social and economic problems unprecedented in kind and magnitude. Unless we are incurable "technocrats," we cannot seriously believe these grave problems can be solved by the part-time pronouncements from on high by professional scientists. Nonscientists must solve social and political problems, but it would certainly help if they could have some background understanding of science, its motivations, its promises, and its limitations.

The scientific community complains that its efforts are rewarded by little more than public apathy. For this the scientist must share some responsibility because until now his attitude toward the public has been cozy—not unlike the patronizing attitude of the erudite physician toward his patient.

It is not enough to engage only in contemplative shoptalk without considering also the arts of communication that make activities comprehensible to the layman. It is up to you, together with the educational community, to help bridge the gap between the scientific and nonscientific segments of society. Keep in mind, also, that many of your future scientific efforts will necessarily have both social and political impacts.

Excerpted from talk by Lawrence R. Hafstad, General Motors vice-president in charge of Research staff, to high school finalists and winners before the National Science Fair.

ADVERTISEMENT—*This entire page is a paid advertisement*

Prepared by U. S. Industrial Chemicals Co.

U.S.I. CHEMICAL NEWS

Oct. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1958

Coppedge Named President of National Distillers

Bierwirth Elected Chairman

John E. Bierwirth, president of National Distillers and Chemical Corporation since 1949, has been elected chairman of the board, and Roy F. Coppedge, Jr., 43, an executive vice-president since May, 1957, has been elected president. The office of chairman has been vacant since 1953.

In their new posts, Mr. Bierwirth and Mr. Coppedge will guide company policy and direct operations. The move was made to provide a broader executive base for the company's growing, diversified business. Net sales in 1957 were $539 million as against $470 million in 1952. Industrial chemicals, petrochemicals and special metals currently account for more than 40% of total operating profits. Total investments in these areas now exceed $190 million.

John E. Bierwirth

Roy F. Coppedge, Jr.

Unique Brake Throttles Flow of Sodium Coolant

Engineers working on the Sodium Reactor Experiment (SRE) at Santa Susana, Cal. have brought a unique solution to the problem of reducing flow of liquid sodium coolant while minimizing thermal stresses on the sodium piping and heat exchanger systems. Flow reduction is sometimes necessary to control rate of temperature change in the reactor core.

Two eddy current brakes — one on the secondary, nonradioactive sodium loop, and the other on the outlet side of the primary loop — straddle the coolant pipes and throttle sodium flow from 1,200 gpm to 12 gpm in two seconds. Thermal stresses on the system are kept well below any damaging level using this braking method.

Attention: Users of Tax-Free Alcohol

The Revenue Ruling covering storage of tax-free alcohol has been expanded for purposes of clarification. The regulation previously stated only that a storeroom which can be securely locked must be provided, of sufficient capacity and substantial construction.

The expanded ruling—No. 58-207—adds that these storerooms may also be used for other supplies, provided they are separated from the alcohol, and provided their presence does not interfere with the proper accounting and safety of the alcohol.

Automation Takes Over Communications at U.S.I.; Speeds Chemicals to Customers

Unique New Teletype System for Communications and Electronic Data Processing Links 40 Locations Via 7,500 Miles of Wire. Sales and Plant Personnel Freed of Paper Work.

Taking a cue from the automatic operations of its many chemical and petrochemical plants, U.S.I. has recently extended automation to the clerical side of its business with a tailor-made teletype and data processing system designed primarily to accelerate delivery of chemicals to U.S.I. customers. Specifically, it does these jobs:

- Completes order processing and invoicing with a single typing.
- Is instrumental in production scheduling.
- Compiles sales, order and production statistics.
- Provides statistics for budget and inventory control.
- Handles administrative messages.

U.S.I.'s new teletype setup interconnects 40 plants, shipping points, sales offices and company headquarters in a 7,500-mile network among 27 cities. It is integrated with standard punched-tape coding and programming equipment, that allows immediate reproduction of an original message anywhere along the line. It also acts as an integral part of an electronic data processing operation which makes information currently and simultaneously available to management, sales, production, research, credit, traffic, accounting.

One Typing Completes Order Handling

Here's how it works. Say an order for ethanol is placed in Chicago. An order form is made up at the sales office. In this operation a tape is produced which transmits complete information to the shipping point at Tuscola via teletype. Here the tape automatically produces combination shipping papers and the invoice. At the same time, the information in condensed form is sent to New York and converted to punched cards for data processing.

MORE

Girls at a U.S.I. sales office producing transmittal tapes for orders. Most information is transferred automatically to the tapes from repetitive data tapes and cards.

Ion Exchange Resins Act As Catalysts in Acetone Cyanohydrin Production

Acetone cyanohydrin can now be made experimentally by reacting acetone with hydrogen cyanide in the presence of anionic ion-exchange resins. These resins perform effectively as heterogeneous catalysts for the reaction, research workers have discovered.

However, a way must be found to prolong their process life before the transition to a successful commercial operation can be made. A two-stage continuous flow reactor has already been developed in anticipation of a rapid solution to the problem. It employs a feed of acetone and hydrogen cyanide in the mole ratio of 5:1. At 25°C, 99% conversion is achieved. This feed ratio is required to prevent swelling of the resin, moderate the evolution of heat, and displace the equilibrium in favor of acetone cyanohydrin.

The principal use of acetone cyanohydrin is for the preparation of alpha-methacrylic acid and its esters which are polymerized to form methacrylate resins.

Phosphoric Acid Shows Promise as Soil Stabilizer

Recent studies have revealed that 1-10% by weight of phosphoric acid stabilizes the fine-grained soils which must frequently be used as foundations for roads, dams and airstrips, and improves the ability of these soils to bear loads. Until these studies were made, no really satisfactory means had been found for solidifying fine-grained soils, which have strength when dry but not when wet.

Phosphoric acid seems to act by forming an insoluble phosphate glass from particles of alumina and silica in the soil. It can be employed in low concentrations, costs little, works fairly rapidly. Soils cured for a few hours under humid conditions achieve high strengths after several days, and very high strengths after a few weeks.

Depending on the initial water content of the soil being treated, it may be necessary to add small amounts of other materials such as fluosilicates for faster cure and maximum wet strength of the stabilized soil.

Oct. ★ **U.S.I. CHEMICAL NEWS** ★ 1958

CONTINUED *Automation*

This new automation is proving invaluable to company and customers alike. When a customer needs some special product or rush service, the U.S.I. salesman, relieved of detail by the automated communications system, is free to set an all-out effort in motion to deliver what the customer needs when it's needed.

Switching center at Cincinnati. Here order and message tapes are received from sales offices for redirection to New York headquarters and shipping points throughout the country.

Esters of Alkyl Aryl Phosphoric Acid Cut Static on Polyethylene

Polyethylene articles with a greatly reduced tendency to accumulate electrostatic charges can be made by incorporating certain esters of alkyl aryl phosphoric acid, according to the claims in a recent British patent. In addition, on polyethylene film and sheeting, these esters are said to reduce static without increasing slip or wettability, as do certain nonionic surfactants used for the purpose. They do not affect the flexibility, water and chemical resistance, strength or heat-sealability of the resin in any way, it is asserted.

The ester is uniformly distributed on the surface of the polyethylene in one of two ways. It may be thinly coated onto the surface of the finished article from solution in a volatile solvent, in the amount of 5 to 100 mg/sq. yd. of surface; or it may be incorporated into the granular resin by milling before fabrication, in the amount of 0.05 to 0.25% by weight.

The resulting articles exhibit little or no static, even after prolonged application of friction, according to the patent, and can be surface-treated by usual methods for better bonding with printing inks.

"Atoms-for-Peace" Show Great Success at Geneva

Mallory-Sharon Among Exhibitors

The U.S. Atomic Energy Commission and 50 U.S. industrial firms participated in the commercial exhibition held September 1-14 at the Palais Des Expositions, Geneva, Switzerland in conjunction with the second United Nations International Atoms for Peace Conference.

Focal point of the American section of the exhibition was a full-scale model of the core of a 150,000 KW atomic power plant. A rotunda surrounding the model contained an information center and displays telling the overall story of the U.S. atomic industry. On either side of the rotunda were the exhibits of the 50 participating U.S. companies.

Objectives of the American exhibition were twofold: First, to demonstrate that U.S. industry and government are working co-operatively in the field of atomic energy. Second, to show that in the U.S. atomic energy is a practical reality.

Highlights of the American section were two "live" atomic reactors of the research and training type; a completely equipped, mobile radioisotope laboratory; the showing of atomic energy films; a display of U.S. technical publications; and a new "master slave" robot.

Mallory-Sharon Metals Corporation, Niles, Ohio — world's largest integrated producer of reactive metals — was one of the principal exhibitors at the show. The company, owned one-third by U.S.I.'s parent company National Distillers and Chemical Corp., devoted its display to zirconium for structural and cladding purposes in thermal reactors and to hafnium for control rods.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Ethanol as a nutrient for cattle, dairy animals and sheep is discussed in a 4-page reprint now available. The alcohol is reported to accelerate rumen microflora metabolism, increasing protein synthesis and cellulose digestion. **No. 1400**

Diethylene glycol dimethyl ether described in new technical bulletin as anhydrous reaction medium for organometallic reactions, solvent for inorganic salts, and for use in synthesis of organoboranes and boron-nitrogen polymers. **No. 1401**

Technical reports made on polyethylene from 1929 to 1957, and now available from the Office of Technical Services of the Dept. of Commerce, are all listed in a 4-page catalog available from Govt. Printing Office for 10¢. **No. 1402**

Copper complex fungicide now offered in pilot plant quantities may also serve as rodenticide. Field tests indicate effectiveness on wide variety of harmful organisms in concentrations between 0.005 and 0.05 per cent. **No. 1403**

Corrosion-resistant metallic filters for fuels and other compounds such as hydrogen peroxide, hydrazine, ethylene oxide and liquid oxygen can now be obtained. Wide range of flow rates and mesh sizes available. **No. 1404**

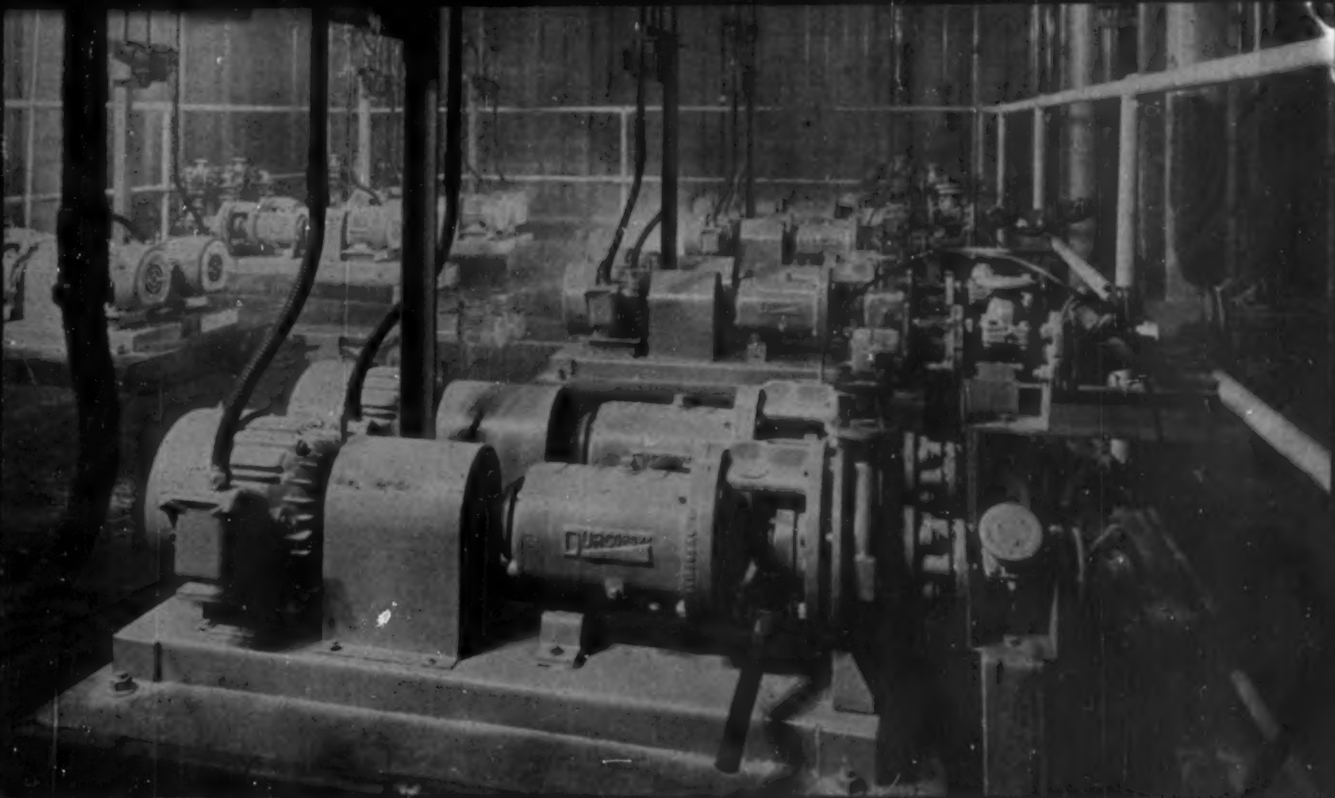
C^{14}-Labeled isooctane (2,2,4-trimethylpentane-2,4-C^{14}) is now available for hydrocarbon and petroleum research on combustion, and for kinetic and mechanical studies. Specific activities to 5 millicuries/millimole can be made. **No. 1405**

New all-polyethylene acid pump now on the market attaches to any 5-pint reagent bottle. Consists of pump body with relief valve, siphon, spout and 4-ounce squeeze bottle. Claimed to deliver 1,000 milliliters per minute. **No. 1406**

Ion exchange resins are discussed in recently up-dated book which can now be purchased. In 466 pages, the book provides detailed information on the nature and preparation of all types of ion exchange resinous materials. **No. 1407**

New silicone rubber compound, reported to be toughest 25 durometer material now available, is suggested for molded and extruded seals, low pressure gaskets, cushions, other parts. Offers tensile strengths up to 1,000 psi. **No. 1408**

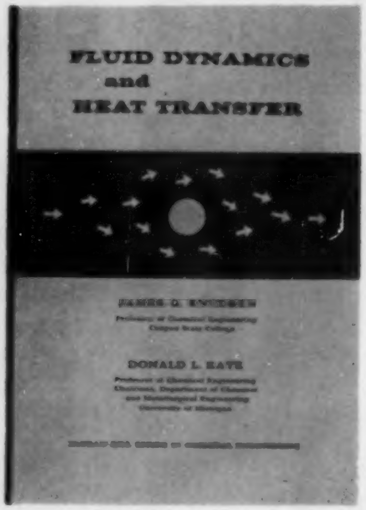
New optical goniometer identifies crystalline substances by simple external measurements of interfacial angles. Catches reflections from various faces in telescope moved around crystal. Claimed accurate, easy to operate. **No. 1409**



marginal notes

FLUID DYNAMICS AND HEAT TRANSFER, J. G. Knudsen and D. L. Katz, McGraw-Hill Book Co., New York. (1958), 576 pp., $12.50.

The underlying purpose of this graduate-level text by two authorities in the field, James C. Knudsen of Oregon State College and Donald L. Katz of the University of Michigan, is to present the basic aspects of fluid mechanics in such a way that they may be applied both to problems in fluid flow and to problems in heat transfer. (The Book is conceived as a one-semester graduate course, and is an expansion of material first published as Bulletin 37 of the Engineering Research Institute at the University of Michigan).



The basic differential equations of fluid flow are developed and applied to ideal flow, laminar and turbulent flow in closed conduits, laminar and turbulent flow past immersed bodies, and flow in heat exchangers. The basic energy equation for fluid flow is derived and applied (along with the momentum equations) to forced convection heat transfer in closed circuits and from immersed bodies.

A practical as well as a theoretical approach has been sustained throughout the book. Illustrative examples have been included to demonstrate the application of relationships presentcd. In addition, the problems at the end of the book will also serve to acquaint the student with the application of the material.

Recent advances in the field are treated in detail. Such new material includes liquid-metal heat transfer,

recent studies of flow in entrances, and much recent work on the analogy between fluid flow and heat transfer.

Of particular interest is Appendix II which contains a treatment of complex numbers, functions of complex variables, and the application of conformal mapping to nonviscous fluid flow.

The book is highly recommended, not only as a text for graduate courses in the field of fluid dynamics and heat transfer, but also for all chemical engineers who wish to be abreast of the latest thought and practice in the subject.

Chemical Process Economics, John Happel, John Wiley and Sons, Inc., 1958.

Review by Wayne E. Kuhn, General Manager of Research and Technical Department, The Texas Company.

The author has done an excellent job of providing techniques which will result in making the general field of chemical process evaluation more of a science than an art. He has been quite successful in bridging the gap between theory and practice. He has a deep sense of theory coupled with wide industrial experience and reduces these to techniques which are quite useful. Detailed coverage of references to other work is given for those who wish to probe deeper into any one subject.

Chemists and chemical engineers will find this book to be a most valuable asset both at the college level and in industry.

The first three chapters give a fairly detailed mathematical approach to a wide variety of problems. The venture profit and venture worth concepts should find wide application. The author recognizes that a rigorous treatment of ways to express profitability is worth the effort only when the basic information available is accurate enough to support such treatment.

Two chapters are devoted to presenting very useful commercial data on investment, operating cost, and risk. The author is to be congratulated on his liberal use of examples. The chapter on "Process Plant Components" is a most valuable one; it deals with optimum design of vessels, pipe velocities, heat exchangers, etc. The Appendix presents much information on time series formulas, cost data, and general rules of thumb for estimating.

Cost estimating techniques are much like those found in the field of statistics. They are no substitute for

continued on page 46

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Gasoline Composition Not Key to L.A. Smog

Changing the composition of gasoline is not a solution to the smog threat in Los Angeles. Smog, attributed by many experts in the field to auto exhaust, is still a problem of growing importance in the Los Angeles Basin, as well as in many other metropolitan areas throughout the entire nation. One proposal—made by political authorities—for control of this eye-irritating, ozone-forming, visibility-reducing, vegetation-damaging smog was to restrict sale of gasoline to that with not more than 15% olefin content.

But, in a report of recent studies conducted jointly by the Franklin Institute Laboratories, Philadelphia, and Stanford Research Institute, South Pasadena, California, and delivered at the just held Salt Lake City Meeting of the A.I.Ch.E., authors Stephens and Schuck showed that reduction of the olefin content of present gasolines offers no promise of alleviating smog symptoms.

Actually, these experimenters found that variations in car design, condition, and operation showed a greater effect on the reaction of exhaust gas with the atmosphere than did the composition of the gasoline fed to the motors. They tested five different cars and four different fuels. Fuel mixtures included an alkylate containing no olefins, a highly-aromatic reformed fuel also containing no olefins, a weighted composite of all fuels sold in the L. A. Basin (15% olefins), and an unrealistically-high olefinic fuel, not presently sold, containing 44% olefins.

All fuels, under the same car-operating conditions, developed the same amount of ozone. All produced eye irritations when car exhausts were irradiated under controlled conditions. The high olefinic fuel, however, produced somewhat more eye irritation than the other fuels tested, for which the irritation level was about the same.

The authors concluded that replacement of the present Basin-composite with fuel containing no olefins would not markedly reduce eye irritations. On the other hand, replacement with 44% olefinic fuel would increase eye irritation somewhat. With respect to visibility reduction, olefin-containing fuels were the only ones which produced an appreciable amount of aerosols. Further experiments, however, showed that this was partially due to the sulfur content of the fuel. (It has no yet been established what percentage of the aerosol and smog particles which restrict visibility in L. A. is caused by auto exhaust).

The formation of ozone—the material which apparently triggers the widely-publicized "smog alerts" in L. A.—was the same for all fuels tested, regardless of the olefin content.

In an interview, W. L. Faith, Managing Director of L. A.'s Air Pollution Foundation and Chairman of the A.I.Ch.E. symposium at which the report was presented, commented to CEP:

"From a technical standpoint, the control of fuel composition is not a promising method of eliminating the smog in Los Angeles, or in any other metropolitan community."

"Further," continued Faith, "limited studies by the Foundation indicate that, from an economic standpoint, the method is even less promising, since elimination of olefins from all gasoline sold in the L. A. Basin area would increase gasoline prices by at least 3c per gallon."

UEC Industry Campaign at 70% Mark

Subscriptions to the Industry Campaign for the United Engineering Center now total $3,524,583—more than 70% of the $5 million goal. Average gift per member engineer employed has been $105.08. The Member Gift Campaign is also rolling along well. As of mid-September, the members societies reported the following percentages pledged: A.I.Ch.E.—26%, AIME—17%, ASCE—13%, ASME—10%, AIEE—10%.

Mass production of ceramic nuclear fuel elements

All operations necessary to processing raw material and assembling fuel elements will be carried out in the new Chattanooga, Tenn., plant of American Lava Co. Fuel pellets ranging from ¼ to 1 in. diameters will be turned out in reactor loading quantities.

Radioactivity measures traces of gas in parts per million

A new instrument (as yet unnamed) developed by Mine Safety Appliances is said to employ a new concept in detection of very small quantities of gas. System involves chemical conversion of trace gases into a cloud of fine particles, use of an ionization chamber for measurement.

SCOPE

Helium for the Future—A Long Range Plan

Twelve million dollars is now available to the Department of the Interior to build a helium extraction plant in the Keyes natural gas field in Cimmarron County, Oklahoma, said to be the richest known deposit of helium in the Free World (2% concentration in the natural gas).

The projected plant will process 50 million cu. ft. per day to extract 250 to 290 million cu. ft. of helium annually, will be operated by the Bureau of Mines. Raw material will be furnished under contract by the Colorado Interstate Gas Co.

The process to be used for extraction of the helium has not been disclosed. However, much recent interest has been aroused by Bell Lab's new process for separation of helium from natural gas by diffusion through glass capillary tubes. According to Bell, its type of equipment could easily be installed directly in a large pipeline. (See CEP, June, 1958, p. 78, and August, 1958, p. 106).

The increased supply of helium which will result from construction of this first plant may give the United States a surplus for a short time. (U.S. production for 1956 is estimated at 191 million cu. ft.). Helium over that presently needed by Government and industry will be stored in crude form underground.

It is expected, however, that, within a few years after the first plant is in operation, helium will again be in short supply. For this reason, the Department of the Interior sent to the last Congress, a few days before adjournment, a proposed amendment to the Helium Act of 1937. The amendment would provide for the financing, construction, and operation of 12 helium plants, to cost $224 million. Total production of helium would be in the range of 32 billion cu. ft. annaully. The crude helium output of these plants would be stored in the government-owned Cliffside, Texas, natural gas field near Amarillo. Tests are said to have established that helium so stored is almost completely recoverable.

Feeling in Washington is that this program is a must and that if private industry does not step into the breach, the government itself will undertake construction and operation of the proposed plants under the direction of the Bureau of Mines.

—J. L. Gillman, Jr.

Theory and practice at Univ. of Illinois

The standard training required by those who plan to enter industry immediately after graduation will be provided at the U. of Ill. by a so-called "Engineering Option", which is a conventional type of chemical engineering program. The extra technical background needed by those who plan to engage in advanced study and research will be provided by a "Physical Science Option". This option gives additional training in advanced physical chemistry, mathematics, and physics, with a decrease in the amount of required electrical engineering, organic chemistry laboratory, chemical technology, mechanics laboratory, and free electives. Choice of the preferred option is made at the start of the Junior year.

CORRECTION

In August 1958 CEP (Scope, page 19), Federal Government spending for research and development was given as $3,782,000 for 1958. Should have been $3,782,000,000. Sorry.

Washington Notes

With the rumored retirement of Paul Foote on October 31, it it believed that the office of Assistant Secretary of Defense for Research and Engineering will be abolished as required under the Department of Defense Reorganization Act of 1958. Indications are that an appointment to the newly-created office of Director of Research and Engineering will be made soon . . . Government fuel technologists tend to be somewhat skeptical of the commercial aspects of a technique to produce "pipeline" gas by hydrogenation of shale. Claimed to be economically competitive, the process, described in a recent Institute of Gas Technology report, is said to accomplish 90 to 100% conversion by hot high-pressure hydrogenation of crushed shale in a one-step procedure to produce a high-B.t.u. pipeline gas . . . The recession in capital investment has levelled off at the bottom and will soon start upward, indicates a just-released report on investment intentions, based on a survey conducted by the Securities & Exchange Commission and the Department of Commerce . . . "There are no technical reasons why the price of oil or U.S. coal (in constant dollars) should increase during the next quarter century," says a report on Nuclear Energy and World Fuel Prices, just issued by the National Planning Association's Special Policy Committee on Productive Uses of Nuclear Energy. "There should be vigorous competition among the fuels in the high-energy cost areas during the entire period," concludes the report, "with beneficial results to all consumers of energy" . . . Significant improvements in Government procurement procedures can be expected as a result of changes in procurement laws recently signed by the President. In particular, "open market" purchases, up to now limited to $500 or $1,000, have been raised to $2,500 for all Government agencies. Financial benefit will be chiefly to small firms. *J. L. Gillman, Jr.*

Fifty million pounds of vat colors seen by 1963

Greatly expanded sales of vat dyestuffs, reaching 50 million pounds by 1963, is the 5-year goal of the Vat Dye Institute.

Prestige of U. S. Engineers Abroad Seen Undamaged

"There is no indication that United States engineers are not looked up to for their technical competence and experience, nor is there evidence that their prestige has dropped within the last six or nine months." So says the EJC Committee on International Relations on the basis of contact with foreign engineers, managers, executives, government officials.

The future must be safeguarded, however, points out the Committee, in a series of recommendations urging a fuller measure of cooperation with foreign engineering associations, both on a government level and in private industrial contacts. "The JCA," says the Committee report, "should always have qualified engineers on its contracting staff and on its missions abroad, so that it may be, at all times, qualified to judge the competence of United States engineers and engineering firms who are to do work in foreign lands. Engineering firms should be selected on a basis of the highest qualifications, and contracts should be negotiated in accordance with the established procedures of other government agencies."

The Government, of course, can't do the whole job. Engineering and construction firms, doing foreign engineering work, should continue to maintain a policy of sending out only well-coordinated teams and well-qualified engineers. "The accomplishment of these people will be the means by which others will judge of our capabilities, and our prestige will remain high so long as our standards are kept high around the world."

The Societies, too, can contribute much toward improving the mutual understanding between U.S. and foreign engineers. The engineers representing the American Societies at meetings of such organizations as EUSEC and UPADI should speak the languages of at least some of the foreign engineers, emphasizes the EJC Committee. They should invite foreign engineers to lecture and to present papers at their meetings in the U.S., and they should encourage participation in their technical meetings by foreign students.

New entry in re-entry race

Phenol-formaldehyde resins may possibly hold the key to some of the problems involved in bringing missile nose cones back to the earth through the atmosphere. Recent research by H. I. Thompson Fiber Glass Co. indicates that a combination of silica fiber and Resinox SC-1008, a special phenolic resin made by Monsanto, resists burn-through better than 15 times the same weight of steel.

Re-entry theory is as follows: As the surface of the new material, called Astrolite, heats up to about 3,000°F, the still-rigid phenolic begins to vaporize, exposing a mat of silica fibers. Although the silica softens into a sticky mass, it does not burn. Like the phenolic, it remains intact until it becomes hot enough to evaporate. The evaporation process removes heat from the material to produce a cooling effect.

If the layer of Astrolite is thick enough, a cone could fall to earth before the protective covering was completely used up. Since the amount of frictional heat generated depends on the speed of fall, faster descents would call for thicker layers of Astrolite.

Titanium—Military Use Down, Industrial Use may Rise

Titanium consumption in 1957, down one-fourth from 1956, reflects less use in military aircraft design. Recent price decreases, on the other hand, coupled with research underway to improve fabrication methods and reduce scrap loss, may make more titanium at a lower price available for process equipment applications.

Vitro, Susquehanna Combine Wyoming Uranium Interests

Vitro Corp. of America and Rochester & Pittsburgh Coal Co., joint owners of Vitro Minerals Corp., have agreed with Susquehanna Corp. of Chicago to combine their uranium interests in Wyoming.

Natural Rubber Shortage Fears Discounted

"Only disastrous political events in rubber plantation areas of the Far East could cause a shortage of natural rubber," says R. P. Dinsmore, Goodyear Tire & Rubber V. P. Even then, adds Dinsmore, the situation could be remedied by acceleration of the current cis-polyisoprene or "natural synthetic" rubber development program. These conclusions, he stated, are based partly on the expectation that polyisoprene or natural synthetic rubber will be available in North America at attractive cost and quality by the early 1960's.

Celanese, I.C.I. join in U. S. Polyester fiber venture

A new polyester fiber, Teron, will be produced and sold in the U. S. by a subsidiary jointly owned by Celanese Corp. of America and Imperial Chemical Industries of England. Mutual advantage of the venture will be pooling of I.C.I.'s research and technological resources with Celanese textile marketing facilities in the U. S. Work on the plant is scheduled to start in 1959 (site is still unselected), eventual capacity goal is 40 million lb./yr.

SCOPE

New Thermoelectric Materials Show "Promising Efficiency"

Termed by Westinghouse "essentially unexplored", a new class of materials has entered the intense world-wide race to find substances which can economically convert the heat of a burning fuel, or other high-temperature source of heat, directly into electricity. Secret of the new Westinghouse development—mixed valence compounds of the transition metals, such as iron, nickel, and manganese. According to the company, the essential ingredients in these new thermoelectric compounds are "just about as common and easy to obtain as those in a dinner plate." They are described as inexpensive, simple to prepare, and not composed of critical elements in short national supply.

Being ceramics, the new materials are inherently stable and chemically inactive, even at very high temperatures. They can be heated indefinitely in air with an open flame without deterioration; they do not require chemical preparation to an extreme degree of ultra-purity; their use raises no technological problems of high-vacuum operation, complex electrical or electronic apparatus.

"Promising efficiencies at temperatures in the range of 2,000 to 3,000° F."—this is the limit of Westinghouse's claims at the moment. The idea, of course, is not new; the principle of conversion of heat to electric power through the use of metallic thermocouples was known as far back as 1820. Only last Spring, the U.S. Navy reported on current research in this field (CEP, May, 1958, Scope, pp 21). The Russians, also, are known to be pushing their efforts in this direction. This is evidenced by a recent Russian book on Semiconductor Thermoelements and Thermoelectric Cooling, published last year in London in English translation.

So far as has been reported, however, efficiencies with metallic thermocouples have been of the order of one percent—much too low for power generation on a commercial scale. Semiconductors, also, exhibit reasonable thermoelectric efficiencies, but not at the required high temperatures for power purposes.

Westinghouse makes no extravagant predictions of imminent mass-scale applications, emphasizes that the work is still in its initial stages. It does believe, however, that for specialized applications, where compactness, light weight, and simplicity are more important than efficiency, these new materials offer promise for practical use in the near future.

Diffusion in pipes and packed beds

Measurements of longitudinal diffusion in circular pipes and packed beds are being made in the University of Pittsburgh's Chemical Engineering Labs by measuring the dispersion of slugs of gas in a moving gas stream. In the schematic diagram of the apparatus, the space between two porous plugs in a one-inch pipe is filled with a gas that absorbs either visible or ultra-violet radiation. By opening and closing appropriate valves, this slug is displaced by a gas that *does not* absorb light in the same spectral region. As the gas slug flows down the 12-foot length of pipe, it diffuses longitudinally and radially. When the slug eventually passes through the beam of a Beckman DU spectrophotometer, the average radial concentration of the *absorbing* gas is recorded. From the shape and size of the recorder tracing, the rate of longitudinal diffusion may be computed.

Major polyvinyl alcohol resin plant for Calvert City

Construction has started on a 20 million lb./yr. polyvinyl alcohol resin plant for Air Reduction Co. at Calvert City, Kentucky. The project will be supported by a pilot plant at Bound Brook, N. J. Cost of both plants is estimated at over $12 million, engineer-constructor is Lummus. The process to be used was obtained under license from Kurashiki Rayon of Osaka, Japan.

Space research contracts go to National Research Corp.

More than $230,000 in Federal research contracts have been awarded to National Research. "Basic studies now underway to determine exactly how missile components react upon re-entering the earth's atmosphere may lead to development of new materials to withstand the tremendous heat and erosion encountered," says the company.

New Flame Cracking Process Available for U.S. License

The new Eastman flame cracking process for the simultaneous production of acetylene and ethylene from light hydrocarbons is now available to manufacturers in the U. S. on a license basis, says Tennessee Eastman. Under a contract agreement, Stone & Webster will design and construct commercial plants.

Solar Power Plant for USSR

UNESCO reports that the Soviets will install in Armenia the largest solar power plant in the world—capacity: 2.5 million kilowatt hours of electricity and 20,000 tons of steam annually. It is said that the installation will have a total area of five acres consisting of 1,300 mirrors which will move automatically along 23 concentric railways to follow the movement of the sun.

Why a Steam Trap Has to Handle "Air"

Low temperatures and corrosion of equipment are often evidence of inadequate trap air venting capacity

Air, with its load of oxygen and carbon dioxide, has an unwholesome habit of interfering with the efficiency of steam heated units. If steam were always free of these undesirable companions, things would be a lot simpler for men-who-operate-plants. Because it isn't, three unhappy situations frequently occur:

1. ***Operating temperatures are subnormal.*** This is a two-part problem. First, an air-steam mixture has a lower temperature than pure steam at the same pressure—see Table A. Secondly, air can "plate out" on heat transfer surfaces as shown in Figure 1. Under some conditions, such an air film will knock down heat transfer efficiency by as much as 50%.

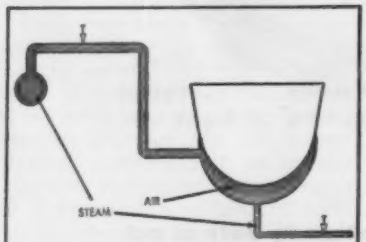


Fig. 1. *How air can "plate out" on heat transfer surfaces. This "insulation" drastically reduces heat transfer efficiency. Armstrong trap operation creates turbulence in the equipment that prevents this.*

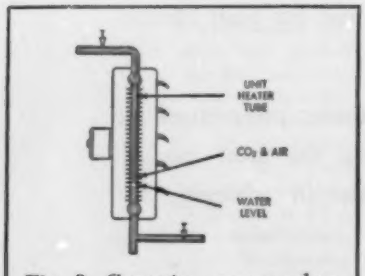


Fig. 2. *Corrosion occurs when units are not kept continuously free of both condensate and air. Armstrong traps discharge both, at steam temperature, as fast as they accumulate.*

2. ***Corrosion rears its ugly head.*** Oxygen and carbon dioxide are real trouble-makers. CO_2 gas goes into solution in condensate, forms carbonic acid and chews away at vulnerable metal sections. O_2 aggravates the situation. See Figure 2.

TABLE A—How air reduces steam temperature.

Gauge Pressure	Temp. of Steam with No Air Present	Temp. of Steam Mixed With Various Amounts of Air (% Air by Volume)	
		10%	30%
10.3	240.1	234.3	220.9
25.3	267.3	261.0	246.4
50.3	298.0	291.0	275.1
75.3	320.3	312.9	295.9
100.3	338.1	330.3	312.4

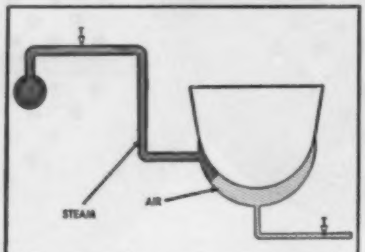


Fig. 3. *When steam is turned on, it takes a trap with extra air venting capacity to provide fast heat-up.*

3. ***Heat-up is slow as a snail.*** Air has a picnic in units that are shut off periodically. Figure 3 pictures the problem. Lines and equipment literally fill up with air. When the steam is turned on it can get in only as fast as the air gets out.

Enter Steam Traps

Curing these steam system ailments involves an operation sometimes called a "trap transplant." It consists of removing traps that don't get the air out and replacing them with traps that do.

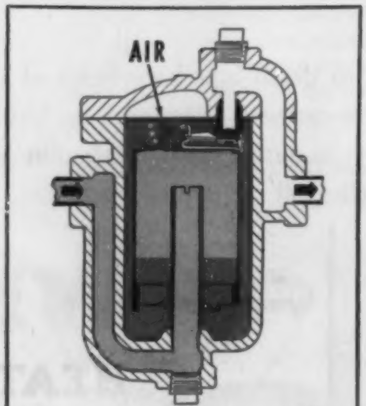
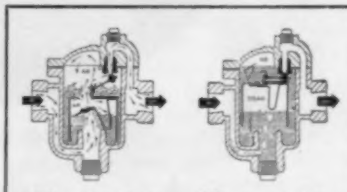


Fig. 4. *Air entering an Armstrong trap passes through the bucket vent and accumulates in the top of trap. When trap opens, air is discharged along with condensate.*

Figure 4 shows how an Armstrong inverted bucket trap continuously vents air. What the picture doesn't show is a built-in plus-value of this trap's design. An Armstrong trap opens suddenly, creating a momentary pressure drop and turbulence in the unit being drained. This breaks up air films and "pumps" air down to the trap so it can be vented.

The vents in standard Armstrong trap buckets will pass all the air normally encountered. In special cases, such as paper machine dryers, the vents are correctly sized larger at the factory to meet the requirement.



Thermostatic vent open. *Thermostatic vent closed.*

Fig. 5. *Open float with thermostatic vent for off-and-on units. When trap is cold, vent is open, permitting air to blow through when steam is turned on. When steam reaches trap, heat closes thermostatic vent. Then, regular bucket vent handles all air coming in with steam.*

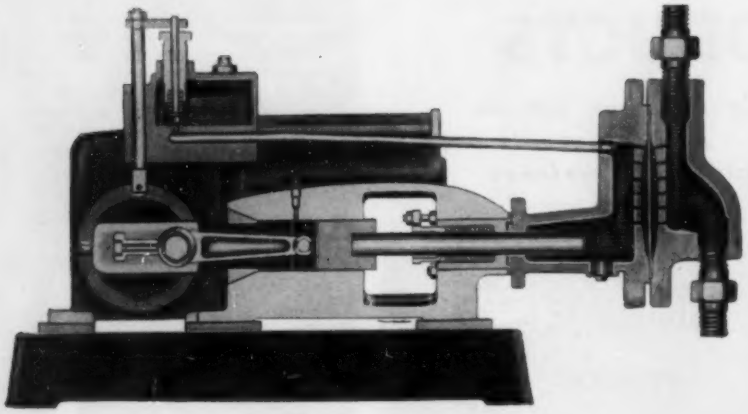
Open Float with Thermostatic Vent

Super air-venting capacity is a must for fast heat-up of low pressure unit heaters, heating coils, steam headers and other units that are on-and-off. Figure 5 shows how the Armstrong open-float-with-thermostatic-vent trap takes care of this.

* * *

The 44-page Armstrong steam trap book covers other features of the Armstrong trap as well as its excellent air handling characteristics. This catalog also discusses trap selection, installation and maintenance. Your local Armstrong Representative or Distributor will be glad to give you a copy. Call him, or write Armstrong Machine Works, 9765 Maple Street, Three Rivers, Michigan.

ARMSTRONG STEAM TRAPS



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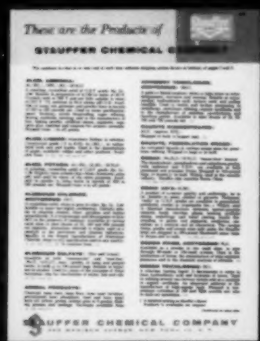

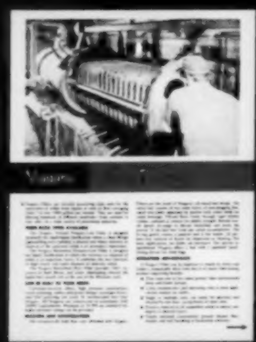

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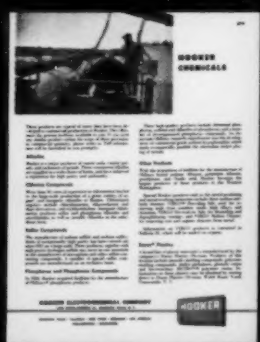

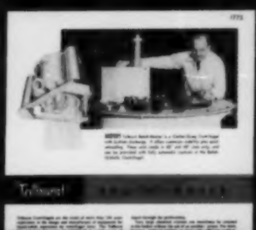

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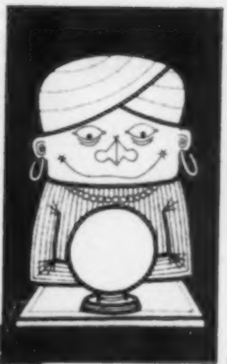

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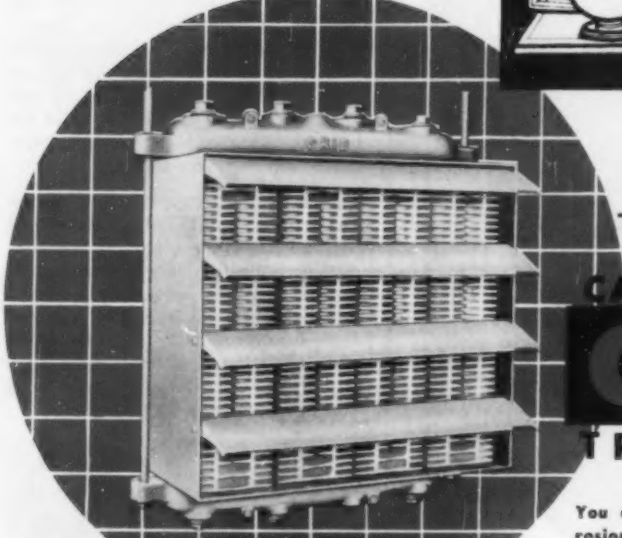

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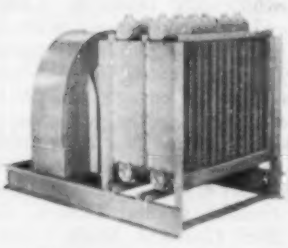

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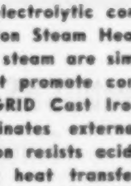

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about our authors

K. L. Mai, who leads off CEP's feature section on heat transfer this month with his discussion of *Rotary Drum Cooler-Flaker Heat Transfer,* has been engaged in a variety of process engineering projects touching on many phases of unit operations and processes. At Shell Chemical, he has worked in the technological department of the Houston Plant where he was responsible for technical service and design work in the plastics and resins section. More recently, Mai has been assisting Shell's synthetic glycerine operation department.

Carl P. Mann, now manager of the Oven Dryer and Lehr Division at Selas Corp., is a recognized authority on the application of high-temperature radiant heat for processing combustible and other manufactured products. His paper on *Heat Transfer Principles Applied to Practical Production Heating Problems* is the end result of 22 years of experience in the field.

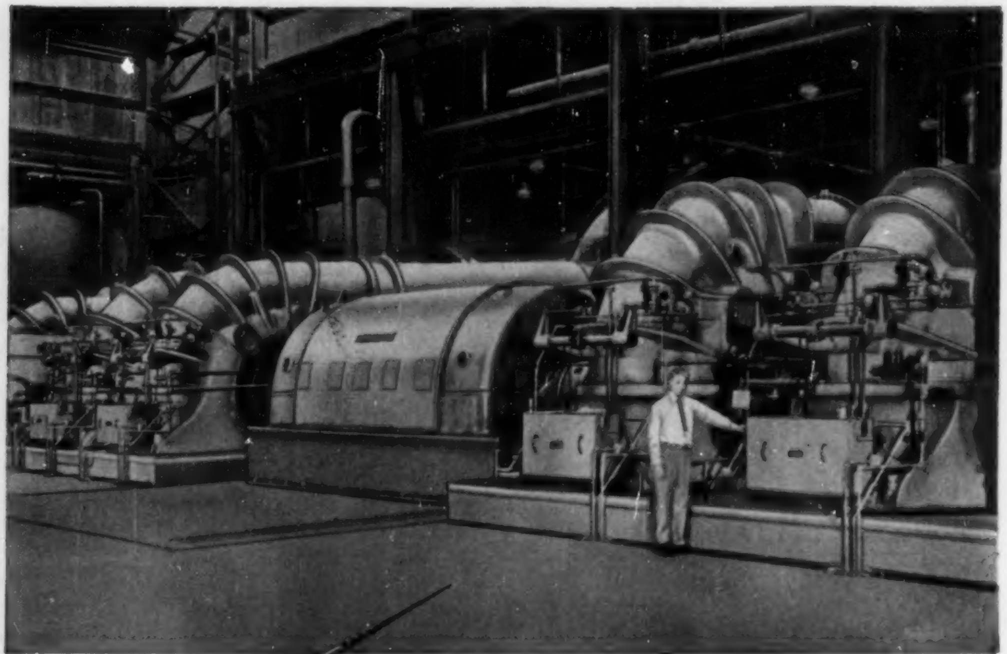
(l. to r.) Authors Mai, Mann, Chantry.

William A. Chantry of Shell Chemical, who with **Don M. Church** authored this month's paper on *Design of High Velocity Forced Circulation Reboilers for Fouling Service,* now heads a group engaged in process studies involved in the production of synthetic glycerine and other industrial chemicals. His experience includes a series of process application heat transfer studies. Church, also with Shell Chemical, heads a group of specialists involved in a variety of areas, including cost analyses, effluent problems, mathematical analysis, and specialized process and chemical engineering problems.

W. R. Gambill (*Boiling Burnout with Water in Vortex Flow*) considers that this paper represents his most important contribution in the field of boiling. Gambill is presently associated with the Reactor Projects Division, ORNL.

Charles H. Gilmour of Union Carbide Chemicals, South Charleston, West Va., is a veteran toiler in the heat exchange field, has been chairman of the A.I.Ch.E. Sub-committee on Heat Exchange.

continued on page 46



Roots-Connersville creates
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about our authors

from page 42

D. S. Arnold, who with **B. G. Ryle** and **J. O. Davis**, writes on *Metal Refining by Solvent Extraction of Leach Slurries*, is presently head of the Chemical Department at National Lead Co. of Ohio.

Ernst Karwat, of the Linde Co. Munich, West Germany is not a newcomer to the pages of CEP. In April, 1957, he wrote on Oxygen Plant Safety; his present contribution, *Some Aspects of Hydrocarbons in Air Separation Plants*, presents the result of recent work in the same vitally-important field.

J. S. Bonner *(Development of a Refinery Simulation Program)* heads Bonner & Moore Engineering Associates, a consulting engineering firm which emphasizes the application of Operations Research and electronic computer techniques to problems in engineering and economics.

marginal notes

from page 25

common sense for the purpose of reaching proper decisions. The author seems to have a real feeling for this.

I have no real criticism of Happel's work. I have some suggested improvements, none of these being critical. It is possible that the first three chapters devoted to the mathematical treament of economics would have best been presented following the chapters on ways to estimate investment, operating cost, rate of return, etc. Perhaps this would not be necessary if the book is used as a text for junior or senior students who have first had an introductory course in the use of economic principles.

Also, I suggest for future editions that the author present information on how labor costs vary as a function of production level for a fixed plant as well as for plants of varying sizes. He touches on this somewhat, but not, in my opinion, in enough detail. Here again, sources of practical experience would serve as the basis for such information.

Applying the principles outlined in this treatise, which cannot be classed as merely another book in the field but a contribution to an area of need, should permit the chemical engineer to design better for optimum economic performance.

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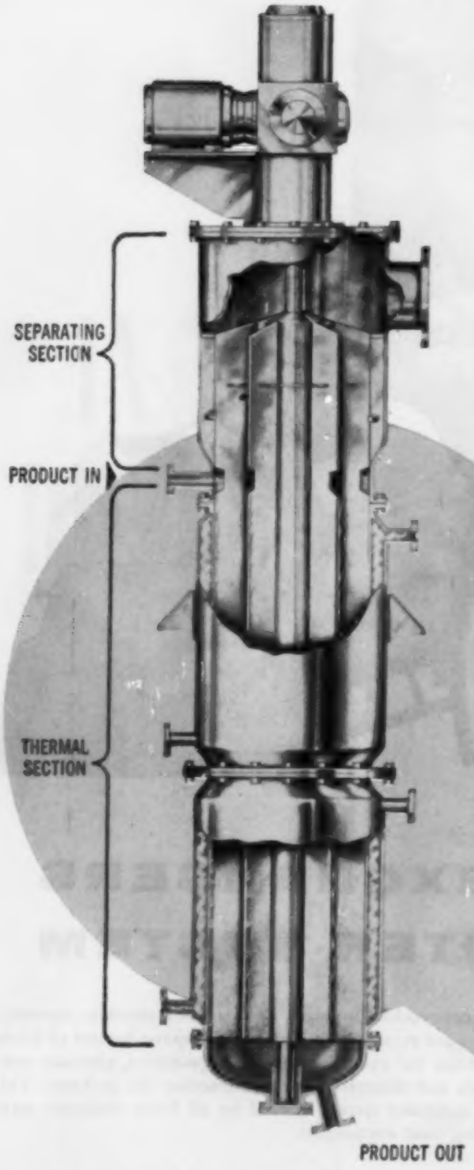

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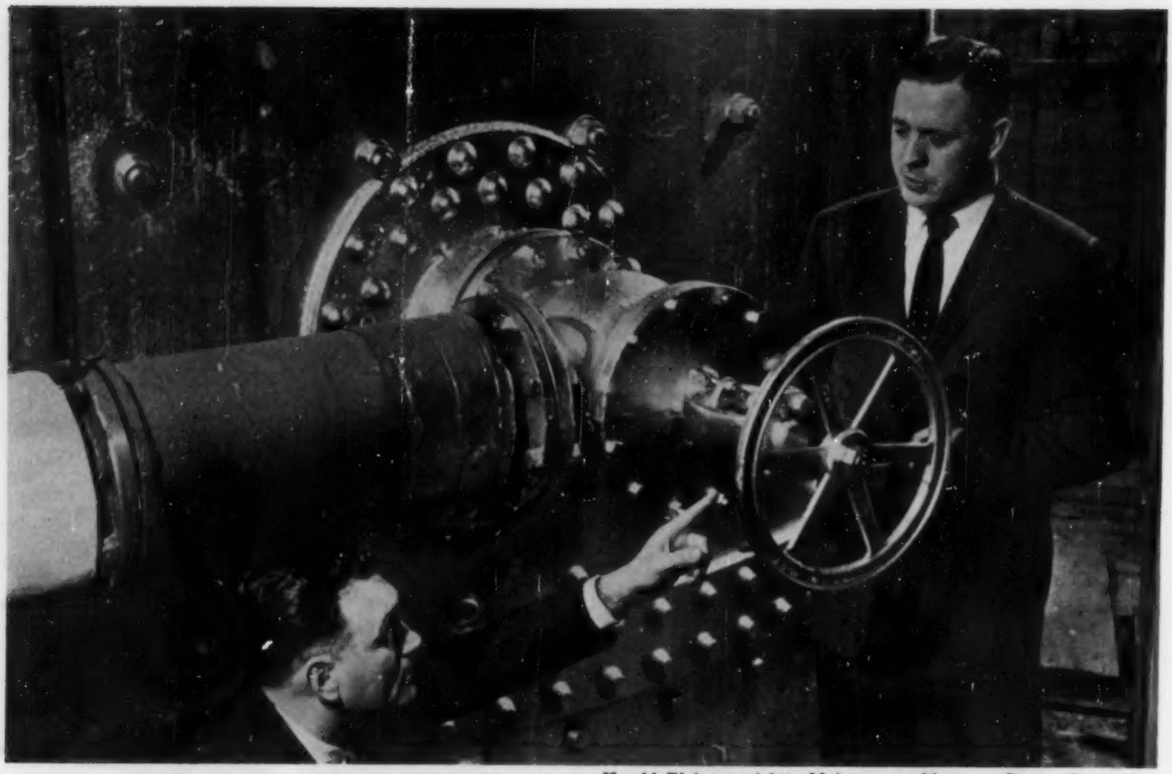

Harold Blakney (right), Maintenance Manager, Brown Company, Berlin, N. H. Left, Frank Hiltz, Vice President Brown Wales Co., Cooper Alloy distributors, Auburn, Me. Center, Cooper Alloy 8" angle circulating valve on digest tank.

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Q. *Why Cooper Alloy valves?*

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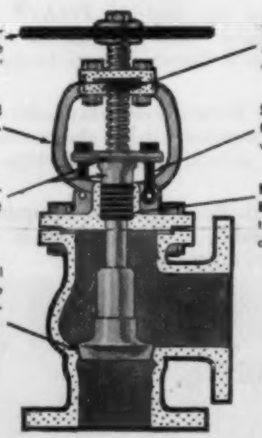
A. Well, these 8" angle valves, for example, have that extra-deep stuffing box to give a tighter stem seal. The seat, level with the outlet, eliminates line pockets and provides maximum flow. These plus extra large hand-wheel all give me less maintenance problems.

Q. *Anything else you like about Cooper Alloy valves?*

A. Yes, I like the engineering service available from Cooper Alloy we have had occasion to use, and the fine fast delivery and service we obtain from Brown Wales' nearby warehouse.



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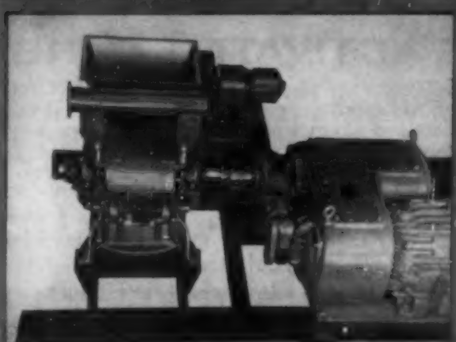

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CEP.....trends

CPI has eyes on Washington, Europe

There are two great arenas where forthcoming events will engage an increasing amount of attention from the far-flung chemical process industry. One is Washington, the other is Europe.

In the first place, Washington has unfortunately discovered the drug industry, and the 350-page report by the Federal Trade Commission on antibiotics while actually highly laudatory to the drug makers has laid the ground work for a rash of lawsuits against leading firms in this field. Although the resulting publicity may be damaging, it is hard to see what actual harm may result to the industry. It does not appear probable for example that the government could fix prices or force price reductions. On the other hand the attack may actually have the effect of freezing prices at current levels because drug firms might be reluctant to attract more attention by undercutting competitors. The investigation however probably will make large mergers in the industry more difficult than ever, but the industry for some time has been going slow along this line. Since there are indications of a swing to the Democratic party in the elections next fall and even the possibility of a Democratic president in 1960, the outlook is for more interference by government controls. The Democratic party sometimes apparently has had a leaning in this direction and the belief that a controlled economy is desirable. This is a factor which perhaps should be taken into account in looking ahead.

Vice-President Nixon recently came out on the side of business by suggesting a small reduction in corporation income taxes, more liberal allowances for depreciation on plants and equipment, and lower personal income taxes. However there is little chance that this can be done anytime in the near future in view of heavy government deficits and the mounting demands for defense spending. So business is unlikely to see any welcome tax relief.

The foreign front continues to be in a turmoil with the Orient replacing the Arab world as the trouble center. No one apparently believes that the situation will develop into an actual war and some good may come of talks with the Red Chinese. However, though a shooting war may not come, economic warfare is becoming more and more acute on all fronts, both with our friends and our opponents. It is likely that imports of chemicals may increase with the growing plant capacity in Germany and Italy.

Improving business in Europe should of course help sales of American products there. The recent revelation that conservative Great Britain is now following the American practice of credit installment buying and monthly payment personal bank loans should help stimulate the English economy.

Meanwhile Russia is apparently preparing the ground work for more aggressive economic warfare. In some quarters it is believed that they hope that they can eventually bring the downfall of the capitalistic world by trade wars instead of military wars over the long range. If they are eventually able to build up large production of civilian goods and let up somewhat on their military expenditures, it is easy to see how they could raid markets in various countries and not only take away part of America's foreign markets but even invade domestic markets.

Soviet First Deputy Premier Mikoyan has said that Russia is ready to work out trade agreements with the United States but that these would have to include removal of high tariffs and laws against trade with Communist countries. This trade he said would help ease tensions of the cold war. Russia wants equipment to produce more consumer goods at home and at first would need credit in their country. While the easing of tension would certainly be appealing, on the other hand ground would be laid for economic trade warfare later in consumer goods, such as automobiles for example, which might be sold in West Europe instead of to the Russian people. This may be what the Russians are really planning instead of raising living standards at home.

Europe and Japan of course have already hit the American market in vitamins, cutting prices and thereby hurting the earnings of the large American vitamin producers. American drug firms are on the other hand operating largely abroad especially in some of the newer drugs where America is ahead of Europe notably in antibiotics, steroids and vaccines. American drug makers expect to become increasingly active both in Europe, Latin America and the Orient. They point out that there are 2,500 million people in the free world against 180 million people in the United States. Granted that most of these foreign millions have little or no spending power, even if 10% of them could become customers for American drugs, the potential is larger than that in the United States. One producer hopes in time to have foreign sales equal domestic sales.

CEP opinion and comment

Government Needs and the Chemical Engineer

Recently, before the United Nations, President Eisenhower held out hope to the nations traditionally without adequate supplies of potable water that the world shortage is on the "threshold of solution."

Such an announcement, particularly when it pertains to work in which the chemical engineer has an important role, is of great interest, not only to those who may benefit, but also to those who will undertake much of the remaining work to be done.

Congress has passed, and the President has signed, a bill appropriating $10 million to the Interior Department for the construction of five demonstration-production plants. Three of these are to be for conversion of sea water, and two for brackish water. Consideration is being given at present to the selection of the types of units to be constructed under this authorizaion. It will, of course, be many months before operating results from the processing units can be measured and evaluated.

It is good news, however, that funds sufficient for large scale demonstration-experimentation are available. It is hoped that the selection, design, construction, and operation of the unit-types will proceed rapidly in line with the President's expressed desire. On the other hand, it is hoped that a really good selection will be made, one which takes into consideration not only the pilot plant data accumulated in recent months, but also the smaller-scale experience with other methods, so that the most likely possibilities will get convincing trial.

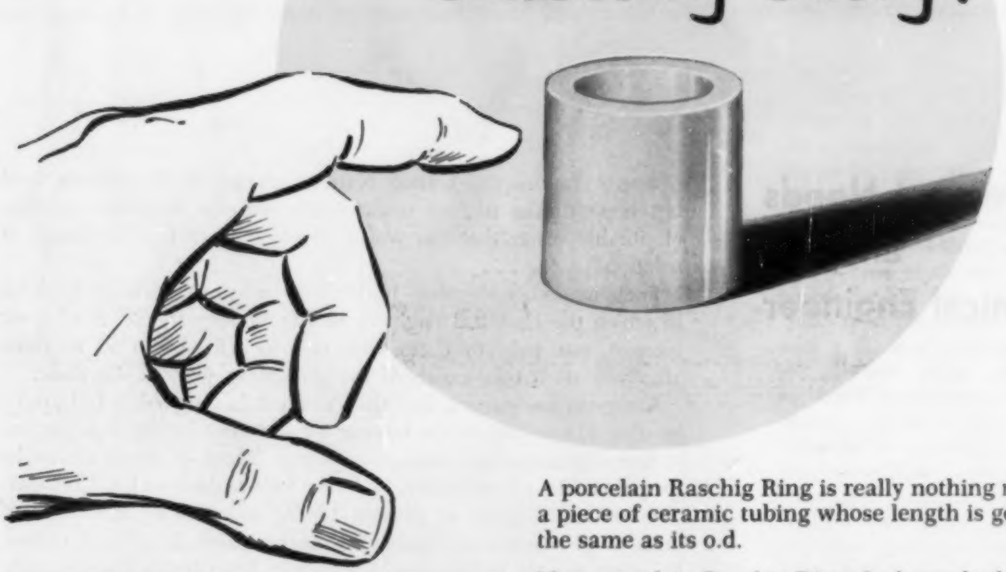
Another instance of governmental interest in what the chemical engineer can do was expressed recently by Governor George D. Clyde of Utah, who, in addressing the recent Salt Lake City National Meeting of the A.I.Ch.E., said:

". . . The future of Utah depends heavily on the chemical engineer." With Utah's resources primarily mineral, as Governor Clyde brought out, the Governor's message implied that his state has high expectations from the application of the *new technology* which has been brought to so many other areas by the chemical engineer's approach to processing problems.

Members of the profession can well take pride in the expressions of confidence implied by these two eminent heads of government.

J. B. M.

What makes a good porcelain Raschig Ring?



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- ☐ Bulletin HDP-56. The use and function of Hold-down Plates.
- ☐ Tower Packings and Packed Tower Design. 232 page text book, written by Max Leva, and published by The U. S. Stoneware Co. It is available in a cloth binding for $8.50 per copy, and in a special paper bound edition for students at $3.50 per copy.

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133-F

a correlation of Rotary drum cooler-flaker heat transfer

K. L. Mai *Shell Chemical Corporation, Houston, Texas*

A mathematical expression is derived from unsteady-state heat conduction which effectively correlates rotary drum cooler-flaker design and operating variables. Extensive tests conducted with plant-sized drum cooler-flakers have shown experimental results to be in excellent agreement with data predicted by the suggested equation.

Rotary drum cooler-flakers are commonly used to continuously cool, solidify, and flake melts. In recent years they have widely displaced equivalent batch-processing equipment since they conserve processing time and working space and eliminate the necessity of finished product crushing and grinding prior to storage and shipment. The operation and the construction of the flaking machines are so simple that they can be applied to the processing of practically all organic and inorganic chemical products that display a definite melting point and possess a truly crystalline solid structure at above ambient temperatures. The only limitation placed on a more extensive application of rotary drum cooler-flakers to materials meeting this melting-point specification is the lack of a firm design basis and the difficulty in establishing optimum operating conditions. This has often limited new installations to the processing of previously tried systems.

Flaker sizing and design to date are largely based on a backlog of processing information available to the equipment manufacturers, and on extensive, time-consuming pilot plant tests. A complete empirical statistical evaluation of flaker performance is impractical due to the complex interrelationship of the numerous operating and design variables and the inaccessibility of sufficient data taken on a common basis. This work was therefore initiated with the object of deriving a theoretical solution to the rotary flaker heat transfer performance which would serve as a springboard to a rational approach to flaker sizing and the choice of optimum operating conditions. This paper covers the method of mathematical analysis chosen and demonstrates the excellent agreement of the results of this analysis with available experimental data.

Flaker operation

The operation of rotary drum cooler flakers is illustrated in the sketch of Figure 1. The flaker, or cooling drum, is mounted on hollow trunnions which are set in bearings. The drum dips to a depth, h, as regulated by a level control, into a shallow pan filled with the molten process material at temperature T_i. A variable speed driver powers the drum which picks up a film of w M lb./hr. of processing material. The film is cooled and solidified during film-drum contact time, θ and then scraped (flaked) from the drum surface by a doctor blade. The flake discharge temperature is T_o. The drum surface may be cooled by cooling water, a brine solution, or a refrigerant, sprayed on the inner drum periphery through manifolded nozzles. At high coolant rates with low coolant temperature drops the coolant temperature may be set at t, the arith-

continued

Rotary drum

continued

metic average of inlet and outlet temperatures t_i and t_o. The process film thickness is shown as R. Primary and secondary operating variables are list- ed in Table 1, the secondary variables being described as functions of the primary units. Of the primary operating variables the flake discharge temperature, T_o, is of greatest importance since product caking and sintering characteristics on transfer and storage are directly related to it. On the same basis this temperature usually limits the capacity of given size flaking units. Among the secondary variables the process film thickness R is limited in range by the physical properties of the process material, i.e., its viscosity, surface tension, degree of surface interaction with the drum surface, etc. The practical limits of R have to be experimentally established.

Table 1. Primary and secondary variables—flaker processing

PRIMARY VARIABLES:

T_o = process stream, discharge temperature, °F.

T_i = process material, feed temperature, °F.

w = processing rate, M lb./hr.

t_i = coolant inlet temperature, °F.

t_o = coolant exit temperature, °F.

rev./min. = drum rotary speed

d = drum diameter, ft.

l = drum width, ft.

SECONDARY VARIABLES:

$R = f$ (w) (rev./min.) (d) (l) (ρ) = process film thickness

$G = f$ (T_i) (T_o) (w) (t_i) (t_o) = cooling water rate

$\theta = f$ (rev./min.) = contact time

Mathematical model

The mathematical model chosen to describe the flaker operation is that of unidirectional unsteady-state heat transfer in an infinite film layer, illustrated in Figure 2. Since the temperature gradient in the X direction of heat transfer is usually 10^3-10^4 times that in the Z direction, and since ideally no temperature gradient exists in the Y direction, unidirectional transfer of heat is postulated to be a valid approximation for this case. In this model the process film layer with thickness R is exposed for a time interval, θ, to the drum surface at temperature t. The amount of heat, Q_x, removed from the process film is a function of the film-drum contact time. Boundary conditions may be defined as follows:

$$\text{At } \theta = 0 \;,\; T = T_i$$
$$\text{At } \theta = \infty \;,\; T = t$$
$$\text{At } x = 0 \;,\; T = t$$

The partial differential equation descriptive of the heat transfer mechanism depicted in Figure 2 is given in its general form in Equation (1).

$$\delta T/\delta\theta = (k/c\rho)\delta^2 T/\delta X^2 \qquad (1)$$

The application of this equation to the flaking process involves the validity of the following assumptions:

1. Negligible heat loss, process film to atmosphere.
2. Lateral drum coverage of 100%. (For maximum utilization flakers are operated at >95% coverage.)
3. Greater than 10 ratio of d/R. (This ratio is in the 10^4 range in plant operation.)
4. Incremental removal of latent heat of solidification in the X direction during the cooling process in the same proportion as heat transfer across the interface. (The film temperature gradient insures this. The assumption that ΔH_s averages in the sensible heat effect applies especially well for cases where $T_f > T_o$.)
5. Approximately constant k within operational temperature limits.
6. Approximately constant ratio of $(k/c\rho)$ within operational temperature limits.

Mathematical solution

As indicated, assumptions 1-3 hold for most plant flaker applications. Limiting the application of Equation (1) to chemical process materials exhibiting physical properties within the limitations of assumptions 4-6, Equation (1) may then be solved by application of a Fourier Series expansion as previously demonstrated by Sherwood and Reed to yield Equation (2) (*1*). Thus for $(k/c\rho)$ $(\theta)/R^2 \geqq 0.5$:

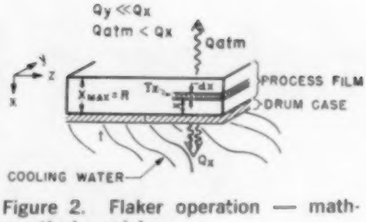

Figure 2. Flaker operation — mathematical model

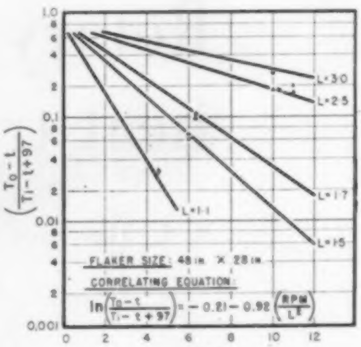

Figure 3. Flaking of organic intermediate "A"—comparison of experimental with predicted data

$$\ln E = \ln(8/\pi^2) - (\pi^2/4)(k/c\rho)(\theta/R^2) \qquad (2)$$

The expression E here represents the ratio of the sensible heat remaining in the flaked product above datum temperature t over all the heat removed in cooling to datum temperature t, i. e., an inverse measure of the cooling efficiency. Inclusion of the latent-heat term follows assumption 4:

$$E = (T_o - t)/(T_i - t + \Delta H_s/c) \qquad (3)$$

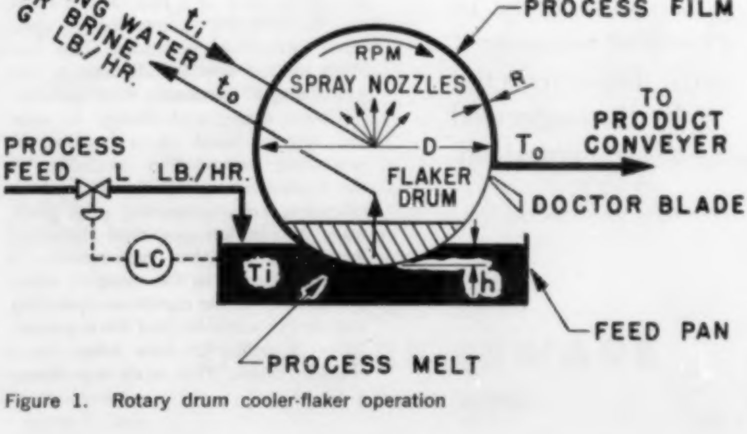

Figure 1. Rotary drum cooler-flaker operation

The contract time θ and film thickness R may, in Equation (2), be expressed in terms of primary operating variables as follows:

$$\theta = (0.0125)\text{rev./min.}^{-1} \qquad (4)$$

$$R = (5.3)(w) / (\rho)(\text{rev./min.})\ (d)\ (l) \qquad (5)$$

Equation (4) predicates a drum circumferential film coverage of 270 degrees. The substitution of the primary operating variables of Equation (4) and (5) into Equation (2) results in the general correlating equation defined by Equation (6).

$$\ln\left[\frac{T_o - t}{T_i - t + \Delta H_s/c}\right] = -0.21 - 1.092 \times 10^{-8} \left(\frac{k\rho}{c}\right)\left(\frac{\text{rev./min.}}{w^2}\right)(dl)^2 \qquad (6)$$

This expression demonstrates that the inverse of the cooling efficiency of a rotary drum cooler-flaker is a logarithmic function of the drum rotary speed, the square of the drum area, and the inverse square of the processing rate. Processing stream physical properties are represented in the term $(k\rho/c)$ as affecting the cooling operation.

Results

To test the validity of Equation (6), available flaker operational plant data were taken with a 48 in. $\times$ 28 in. (drum dimensions) flaker over a wide range of operating conditions. Upon insertion into Equation (6) the expected flake discharge temperature, T_o, was calculated. A comparison of these calculated values of T_o to experimentally measured values showed a standard deviation of less than 3°F. An example of the test information received with an arbitrary organic intermediate is shown in Table 2.

Figure 3 plots the data of Table 2. The correlating equation shown was derived from Equation (6), by insertion of the corresponding drum dimensions of $d = 48$ in. and $l = 28$ in. and the physical properties of the organic intermediate.

Preliminary data received from tests with an additional 48 in. $\times$ 60 in. flaker unit further substantiated the excellent agreement of plant operational data with that predicted by Equation (6).

Method for design

To size a flaker (dl) for the cooling of w M lb./hr. of a material of known physical properties (ρ, k, c, ΔH_s) from a feed temperature T_i to a discharge temperature T_o, the following procedure is suggested:

1. Establish availability of the cooling medium (G) and its feed temperature (t_i) and calculate the average cooling water temperature (t) by the heat balance of Equation (7).

$$t = t_i + \left(\frac{w}{2G}\right)\left[(T_i - T_o)c + \Delta H_s\right] \qquad (7)$$

2. If such data are unavailable, experimentally determine the minimum flaker process film thickness, R, at which 100% lateral drum coverage can be attained under conditions of T_i, T_o, and t. A pilot plant or bench-model flaker may be employed for these determinations as variations in (dl) will have little effect on the value of minimum R.

3. Insert the value for minimum R into Equation (5) and solve Equations (5) and (6) simultaneously for unknowns (r.p.m) and (dl). The r.p.m. thus obtained will be the optimum rotary drum speed and (πdl) will represent the minimum drum circumferential area required for the specific flaking operation.

Table 2. Application of Equation (6) to actual operating data.

T_i °F.	T_o °F.*	t °F.	w M lb./hr.	rev./min.	$\frac{T_{o-t}}{T_i - t + \Delta H_s/c}$	T_o, °F. by Eq. (6)	Error in T_o Prediction, °F.
342	219	139	3.04	11	0.267	225	+6
342	194	141	2.48	10½	0.177	193	−1
342	193	141	2.45	10½	0.174	192	−1
342	197	147	2.47	11	0.171	194	−3
341	195	140	2.47	10	0.184	197	+2
340	201	140	2.53	11	0.205	198	−3
340	172	143	1.65	6½	0.090	175	+3
337	174	142	1.73	6½	0.109	174	0
342	166	146	1.56	6	0.068	167	+1
342	164	146	1.52	6	0.062	167	+3
345	155	146	1.13	4½	0.030	154	−1

* Experimental.

Conclusions

A mathematical expression was derived which effectively correlates rotary drum flaker design and operating variables for processing materials showing little change in thermal properties during cooling and solidification. The expression fits actual operating data within a standard deviation of 3°F., based on flaker-discharge temperature. Based on this excellent agreement, the expression should be useful as a basis for rotary drum cooler-flaker design and the choice of optimum operating conditions.

NOTATION

- G = coolant rate, lb./hr.
- ΔH_s = latent heat of solidification, B.t.u./lb.
- w = processing rate, M lb./hr.
- R = process film thickness, ft.
- T = process film, average cross-sectional temperature, °F.
- T_i = process material, feed temperature, °F.
- T_o = process material, discharge temperature, °F.
- T_f = process material, freezing point, °F.
- θ = process film, drum surface contact time, hr.
- c = process material heat capacity, B.t.u./lb./°F.
- d = drum diameter, ft.
- h = depth of drum immersion, ft.
- k = process material thermal conductivity, B.t.u./(hr.)(sq. ft.)(°F./ft.)
- l = drum width, ft.
- t = average coolant temperature, °F.
- t_i = coolant inlet temperature, °F.
- t_o = coolant exit temperature, °F.
- ρ = process material density, lb./cu. ft.

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Presented at 1958 Heat Transfer Conference, Chicago, Ill.

Heat transfer principles applied to practical production heating problems

New uses of the best technical information at hand in heat transfer operations will increase our productive capacity.

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There is probably no manufactured product that does not in some stage of its fabrication require heat, and in the vast majority of instances, heat must be applied several times.

This fact, therefore, points up the importance of determining both the proper heating cycle to produce the desired end product, and also the best way of transferring the required heat to the product. It might well be said that the first is to determine what to do, and the second is to determine how to do it. This presentation dwells largely on the latter. Because of the writer's familiarity with industrial gas heating applications, emphasis on this aspect will be apparent.

Heat and color printed glass

As an illustration, an examination of some of the heating operations encountered in the manufacture of color printed glass bottles can be made. First, the raw products entering into the particular glass are melted in a furnace, then the molten glass is fed to molds in a forming machine which gives the bottles their shape. From the forming machine, the newly molded bottles are reheated and cooled through an annealing lehr, after which ceramic colors are printed on them; the bottles are then reheated and recooled in a decorating lehr preparatory to inspection and packaging for shipment. The above steps involve five heat transfer stages, viz; initial heating, then the two stages of heating and cooling in each of the annealing and decorating lehrs.

C. P. Mann is manager, Dryer & Lehr Div.

Each of these stages presents its individual heat transfer problem, though in this example there are duplications. In both the annealing and decorating lehrs, the ware must be heated to a temperature above the annealing point, and then be cooled at a controlled rate to a temperature suitable for handling. In the case of the annealing lehr, however, the ware enters the lehr at a relatively high temperature, and it is necessary to add only the heat which has been lost in transit between the forming machine and the lehr, and also to bring all portions of the bottles to a uniform temperature. In the case of the decorating lehr, the ware enters the lehr at room temperature, so it is necessary to add a large amount of heat at a carefully controlled rate, first to evaporate the solvents from the printed surface, and then to raise the bottle to a uniform temperaure above the annealing point.

It is a rather simple matter to heat and cool a glass bottle or almost any object, provided the element of time is unimportant. It may be heated slowly, and cooled slowly, and the resultant product will be satisfactory. When, however, the matter of an economical production rate becomes a consideration, then this simple matter becomes complex.

In the light of present-day knowledge, any particular formulation of glass of a certain thickness has a certain optimum rate for heating and cooling, and these rates may be calculated. While heating at a slower rate and cooling at a slower rate will produce a satisfactory product, yet it is obvious that any extra time consumed in performing these operations beyond the calculated optimum will result in increased costs of production and equipment. The problem then arises as to how to attain these optimum rates.

Figure 1 (curve A) shows a mathematically derived short annealing cycle. It shows the temperature for glass entering the lehr slightly cooler than the annealing point, the lower temperature being the result of the heat loss between the forming machine and the lehr. Curve B shows a curve for average commercial practice, where the time in the lehr is three to four times the theoretical. Reasons usually given for this great disparity

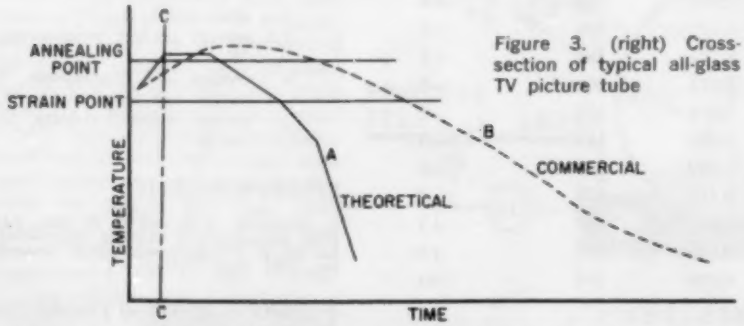

Figure 1. Time-temperature curves for a typical annealing lehr

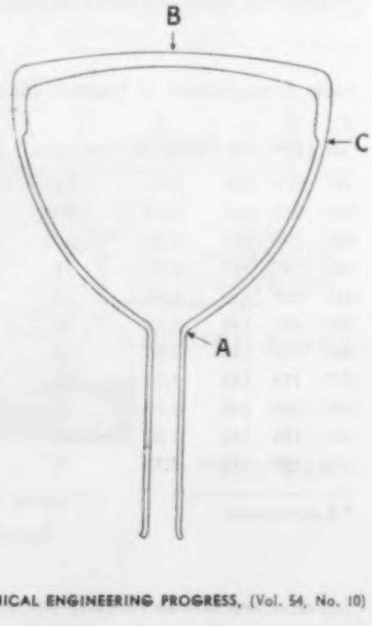

Figure 3. (right) Cross-section of typical all-glass TV picture tube

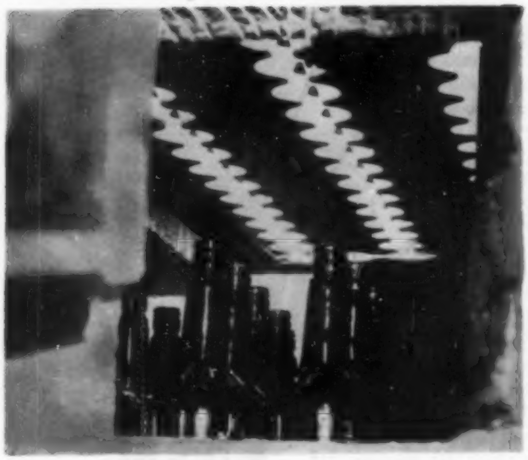

Figure 2. Radiant roof at lehr entrance

are: difficulty in obtaining uniform temperatures across the width of the lehr, and difficulty in controlling the temperature gradient, or heating and cooling rates, as the work travels the length of the lehr. Another reason, frequently not recognized, is failure to take advantage of the fact that glass can be heated and cooled with the development of less internal stress by radiant heat transfer as contrasted with convection heat transfer.

Preheating process

Improvements in control and heat application are constantly being made so that in the future the commercial curve will more nearly approach the theoretical curve. An additional improvement which has resulted in production increases of over 20% has been the recent practice of preheating the glass before it enters the lehr so that upon entrance it has attained a temperature at, or above the annealing point, which has the effect of shortening the time in the lehr as indicated by the line C-C. This preheating is accomplished by installing radiant roofs above the glass just ahead of the lehr entrance, this radiant heat being directed at the upper part of the glass, where the heat losses in transit from the forming machine are greatest. Figure 2 is a photograph of such an entrance roof to a lehr.

Heat transfer to TV picture tubes presents an interesting problem in two manufacturing steps of (1) baking on the screen, and (2) evacuating or exhausting the tubes. Figure 3 shows a typical cross-sectional view of an envelope, illustrating the nonuniformity of the thickness of the glass. In many early installations these envelopes were heated and cooled by convected air. The thermal conductivity of glass is very low, being in the order of 6 B.t.u./(hr.) (sq. ft.) (°F./in. thickness) compared with 2,600 for copper. Convection heating (or cooling) is a slow process because the heat must travel from one surface of the glass to the other by conduction through the glass. Radiant heat, however, being a wave form of energy, partially penetrates the glass which absorbs this heat throughout its thickness (a process sometimes referred to as heating in depth), therefore, the heating rate (or cooling rate) is relatively high. Radiant heat is particularly efficacious during the screen baking cycle because the objective is to bake out the fluorescent coating which has been placed on the internal surface of the face plate of the bulb. The radiant energy penetrates through the glass and bakes the internal coating rapidly with the development of much less stress in the glass than by convection heat.

Similarly, the internal fluorescent coating on tubular fluorescent lamps is baked by radiant heat. In this case, in order to properly bake this coating, it is necessary to heat the lamps to a temperature near the softening point of the glass. It is also necessary to rotate the lamps as they travel under a radiant roof so that every element of the circumference will receive the same heat treatment; so that straightness of the lamps will be maintained, and out-of-roundness or collapse of the thin wall will be prevented. Figure 4 shows a radiant roof lehr designed to rotate the lamps as they progress through the lehr.

The latest practice in heating and cooling TV bulbs during the exhaust cycle is to enclose them in a metal envelope so as to exclude convection currents, and heat, or cool, this enclosure, which in turn transfers the heat to the bulb in the heating cycle or from the bulb to the envelope in the cooling cycle by radiation.

There is a well-known building material fabricated into panels of various thickness from ¾ to 3½ in., composed of excelsior, the strands of which have been impregnated with a water soluble cement. The manufacturing process consists in forming a continuous mat of this material of the desired width and thickness, then drying this mat and curing the cementious material by heat.

Convection heat offers an ideal solution to this problem because the heated air, under blower pressure, can be forced through this mat, thus contacting every strand of the excelsior, evaporating, and removing the moisture by absorption and heating the whole body of the product, thus curing the cement.

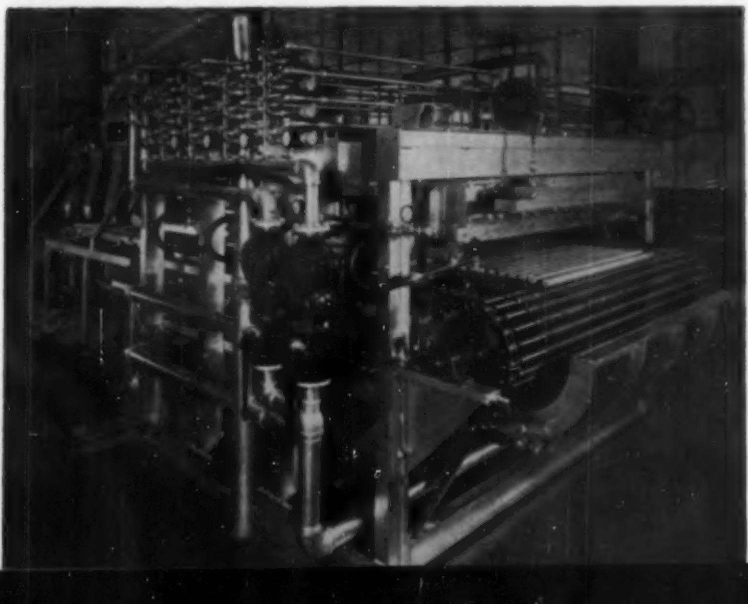

Figure 4. Entrance end of radiant furnace for baking fluorescent tubular lamps

Production heating

continued

On the other hand, the surface coating applied to asbestos shingles or acoustical tile is most advantageously dried and cured by passing this material under radiant burners with the coated side on top and the radiant heat directed downwardly on the top surface. Processed in this manner, this coating can be cured in about one third of the time required by convection heat.

Figure 5 shows a diagram of a radiant ceramic gas burner. The air-gas fuel mixture is supplied through the central tube and through a multiplicity of ports in the burner tip which directs the burning products of combustion so that they sweep the ceramic cup-shaped surface. Because of the insulating character of the ceramic body, the surface of the cup becomes incandescent, thus converting the heat energy of the products of combustion to radiant energy. Figure 6 shows a radiant surface developed by mounting a multiplicity of radiant burners in a panel.

An interesting contrast in methods of transferring heat to steel strip or sheets in what to a casual consideration would seem to be practically identical applications, is the drying of surface water from steel preparatory to a subsequent cleaning or coating operation, and the drying of the water from this same steel after it has been coated later with a water soluble coating. In both cases, in the interest of obtaining optimum production speeds, it is necessary to apply heat.

High velocity burner

In the first instance, radiant heat directed on the surface of the metal would be one way of drying the surface, but in this case, convection heat can be used in a way to be more efficient and rapid. By generating this convection heat in an ingenious and unique burner, the heat may be applied at a very high temperature and exceptionally high velocity so that the water removal is accomplished by the combination of the heat and actual physical scouring of the metal surface by the turbulent energy of the air and products of combustion.

Figure 7 is a sectional view of one of these high velocity burners. It is basically a refractory-lined furnace in which heat is released at rates as high as 40,000,000 B.t.u./(cu. ft.) (hr.), at temperatures of approximately 3000°F. and burner pressure 30 in. w. c. with velocity at the outlet up to 2500 ft./sec. Higher burner pressures at correspondingly higher combustion rates are readily attainable.

Premixed air and gas burn inside the burner from numerous precision ports in ceramic structure E. Combustion proceeds along and in contact with the surface of a high temperature insulating refractory lining C, closed in at the outlet to form a nozzle or blast opening B. The superheated blast A issuing from the nozzle is then directed at the work. The entire assembly is encased in shell D attached to a plenum chamber F with the fuel fed in at the threaded pipe connection G.

In applying these high velocity burners (or heat generators) to the steel strip or sheets, the outlet of the burner is placed close to the steel surface to utilize as much of the high temperature and velocity as possible, and usually at a slight angle against the direction of travel of the steel to obtain the most effective scouring action. In actual operation, it may be observed that the water film is partially lifted from the surface and evaporated while in suspension by the almost instantaneous mixture with the hot products of combustion of the burner. It can readily be understood that this is a relatively violent drying process.

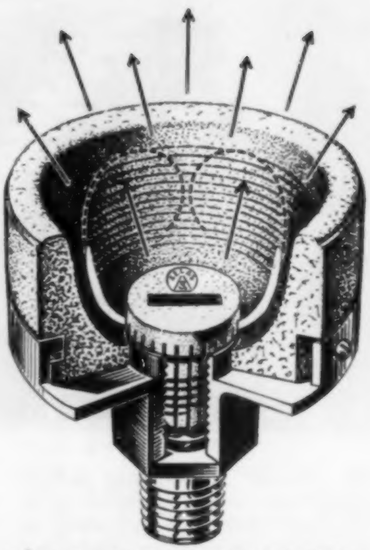

Figure 5. Sectional cut of ceramic radiant burner

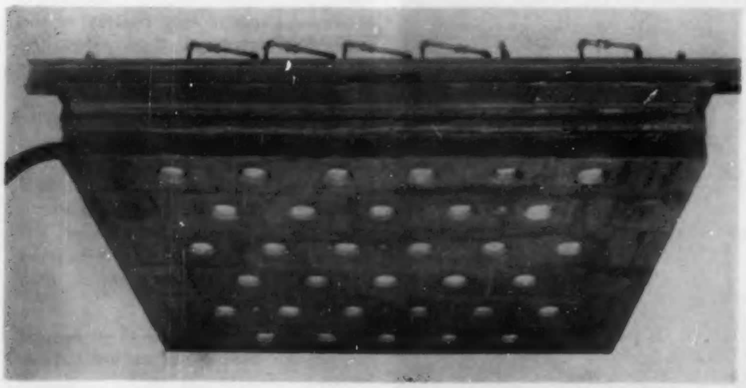

Figure 6. Photograph of radiant panel

In drying the moisture from the water soluble coating on strip, such a violent treatment, while effective so far as moisture removal is concerned, could not be permitted because it would result in partial removal of the coating as well as the water. In this instance, radiant heat transfer is most efficacious. The coated surface of the steel is passed beneath a radiant roof which directs its heat on the coating and evaporates the moisture, as in the case of the coated shingles just mentioned.

An excellent illustration of the ideal application of heat transfer by radiation and by convection, (and interestingly enough in successive heat-treating operations on the same article) is found in the production of tempered glass.

Tempered glass

Tempered glass is glass that has been toughened by heat treatment, and is used where extra strength may be required such as the protective glass fronts on TV receiving sets or where glass is subjected to rapid thermal changes, such as glass fronts on cooking ovens, broilers, etc.

Glass used in the production of articles of this character has a tensile strength in the order of 8000 to 10,000 lb./sq. in. and a compressive strength of about ten times this amount. Annealed glass contains no internal

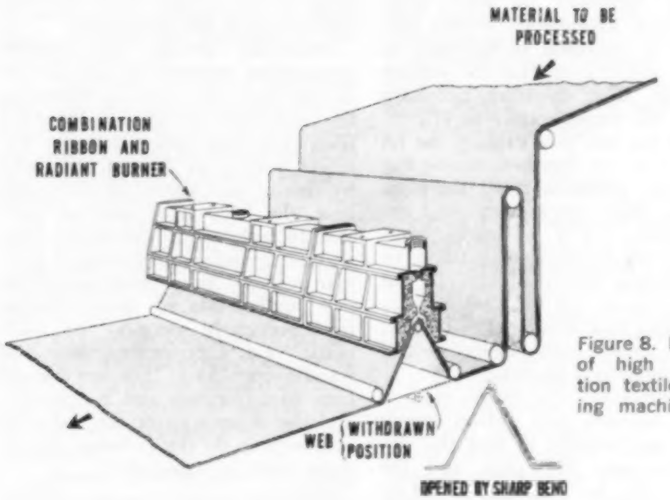

Figure 8. Diagram of high production textile singeing machine

stresses so that if such a piece of flat glass is supported on the edges and is pushed on one side, the opposite side of the glass is immediately subjected to tensile stress, and as soon as this stress exceeds its tensile strength, the glass will break. Tempered glass, on the other hand, is glass that has both outer surfaces in compression while the center element is in tension. When such a piece of flat glass, supported on the edges, is pushed from one side, the opposite side being under initial compression will first lose some of its compression stress, and if the pushing pressure continues increasingly, glass failure will not occur until enough pressure has been exerted to release the initial compression stress on the opposite side, and in addition, be subjected to additional tensile stress exceeding the tensile strength of the glass. This explains why the tempered glass is so much stronger than ordinary annealed glass.

Heating and cooling

The process of tempering glass is to heat the whole mass of the glass uniformly to a high enough temperature to permit slight viscous flow of the glass, and at this point chill the two outside surfaces of the glass rapidly to a temperature below the point of viscous flow so that they will attain a rigid dimension while the internal elements of the glass are still in the state of viscous flow, and finally permit the whole glass to cool. As the inner elements of the glass cool off, they contract, but in so doing, the outside elements are put in compression. Heat transfer to the glass by radiant heat is ideally suited to the first operation where the whole body of the glass must be heated rapidly throughout its whole mass, and heat transfer for cooling the glass by convected air is ideally suited to the second operation, as this air cools the surface first, the inner core of the glass then being cooled by conduction to the surface.

In the textile industry, there is one heat transfer problem that is not encountered in any other industry. After weaving, certain kinds of cloth have fine particles of lint protruding from the surface of the cloth. In order to receive acceptance by the clothing trade, this lint must be removed, and this is commonly done by burning off —a process known as singeing.

This singeing is accomplished in a number of different ways, some by contact of the cloth on a heated metal surface, but more generally by direct flame impingement. One of the more recently developed singeing machines which attains an unusually high production speed and uniform singe, uses a combination high velocity flame and radiant burner in conjunction with a mechanism for bringing the cloth in proper position relative to the burner, and at the same time causes the lint to be raised from the cloth surface so as to present a favorable aspect for complete incineration by the heat of the burner. Figure 8 shows diagrammatically the construction of the burner, the operating principle of the mechanism, and the method of raising the lint from the cloth surface.

Figure 7. Sectional view of super-high velocity burner

In operation, the cloth is positioned in close proximity to the high velocity flame at the apex of the V-shaped assembly, and to the radiant refractory-lined walls. Not only is the lint entirely consumed, but the burned particles are blown away from the cloth, eliminating the necessity for a succeeding brushing operation which is often used with other singeing methods.

Recently there has arisen a new concept for the rapid drying of granular or pelletized materials, particularly those which can tolerate high temperatures. This consists in installing a radiant roof over a vibrating conveyor, which may or may not be of the natural frequency type, thus accomplishing two objectives: heating and/or drying the materials, and at the same time giving these materials what the economist would term added place value at reduced cost because the materials are being simultaneously heat processed and transported. In this case, heat transfer to the material is accomplished by both radiant and convected heat, because the radiant heat is directed downwardly on the material below, and at the same time the products of combustion are confined between the radiant roof and the conveyor hearth so that the particles of material are propelled through the hot products of combustion as they are vibrated off the hearth surface. This action might be described as being similar to a breathing action.

Waterproof paper bags for handling hygroscopic materials, such as portland cement, are made by laminating two pieces of creped paper together by means of a waterproof adhesive, such as asphalt. This process requires that the two paper webs, which contain a high moisture content from the the creping operation, be brought together with the asphalt adhesive between them, and at this point they are heated for the dual purpose of melting the asphalt to attain adhesion, and to dry the two paper webs. Be-

continued

Production heating

continued

cause of the moisture-proof barrier between the paper webs, it is necessary to remove the moisture from the paper in a direction away from the center of the laminated web. This heat transfer problem is solved by passing the dual web between two radiant panels, thereby withdrawing the moisture from both sides at once, and at the same time melting the asphalt; thus proper adhesion is assured.

In some radiant heat transfer operations, the rate of heat transfer is so rapid and the process so critical that proper control of the heat input is just as much of a problem as the heat transfer itself.

The flowing of electrolytically deposited tin on steel plate is an illustration of this. When tin is electrolytically deposited on steel strip, microscopic examination reveals that the tin is deposited in the form of minute globules, so that the surface is porous. It is, therefore, necessary to heat this tinned surface to 475° F. to melt the tin, thus causing the tin globules to run together, closing the pores and giving a shiny tin plate surface. This temperature must be held within ±5° F. to prevent overheating and consequent oxidation, or underheating and nonfusion of the tin. At speeds up to 1200 ft./min. the heating time is in order of 1½ sec., so that almost instantaneous control of temperature is essential.

In production, the tinned plate is passed between two radiant panels which are movable so that the distance between the plate and the panels can be varied. An optical pyrometer is focused on the strip and the panels are automatically moved closer to, or farther away from the strip, in accordance with impulses received from this instrument.

Practically all the heat transfer applications referred to here are relatively new, for instance, increasing the production rate of glass-annealing lehrs by adding radiant heat, the drying of coating on shingles and metal by radiant heat instead of convection heat, the removal of moisture from steel by high velocity convection heat, and the drying and conveying of granular materials in one operation. These new applications all mean changes from previously accepted and traditional ways of performing these heat transfer operations. They are changes born of inspiration and imagination, and the acceptance of the industrial challenge to do things better and do them more economically.

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Design of High velocity forced circulation reboilers for fouling service

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A design method for high-velocity forced-circulation reboilers used in fouling service, determines optimum tube velocity by considering the effect of velocity on capital, maintenance, and power costs.

Both capital and operating cost savings have been obtained through a knowledge of high-velocity heat-exchanger design for fouling services. Experience gained with test installations has led to a series of highly successful forced circulation units using 10-30 ft./sec. tube velocities in fouling services.

For the purposes of this discussion fouling service is defined as one in which the over-all heat transfer coefficient is reduced because of fouling from the design clean value to the design dirty value in less than six months. Cases of fouling on the tube sheets or at the return bends, as well as the normal tube-wall fouling, must be included in this category. The studies, summarized in this article, included exchangers which originally required cleaning in 6 to 180 days. The revised equipment does not require cleaning more often than twice a year.

A growing number of rapidly fouling services are being encountered in chemical processing, and in the last five years a number of high-velocity forced-circulation reboilers have been successfully placed in operation. Typical applications include exchangers used in units processing chlorinated organics, solid catalyst slurries, concentrated aqueous solutions of mixed salts and heavy residues, and high boiling organic-polymer-salt mixtures. In these services rapid fouling is caused either by high tubeside film temperatures, which lead to polymerization and tar and coke formation, or by salt and heavy polymer laydown due to evaporation on the tube walls. Normal fouling due to impingement and tube plugging is greatly accelerated when even a light film of sticky organics forms on the walls.

Several procedures have been used

to maintain production using normal exchangers operating in such services. Four of these are discussed as examples:

1. *Shut down and clean out whenever necessary.* The least initial investment is required but the maximum operating expense, including the value of production lost as well as the maintenance expense, is incurred.

2. *Clean routinely on a schedule.* This permits optimum scheduling of production and maintenance forces but inevitably requires cleanouts before necessary.

3. *Overdesign the installed surface to lengthen the cleaning cycle,* that is, select a high fouling factor. The initial cost must be evaluated on the basis of reduced maintenance vs. increased production.

4. *Install parallel units.* Switching heat exchangers without interruption of production saves the value of production that would be lost during a downtime for cleaning, but the initial cost is high. A rule-of-thumb indicates that parallel units become profitable when the tubes become fouled in less than a month.

It is obvious that each of these alternates has drawbacks. The use of high-velocity forced-circulation reboilers has proven more attractive than any of the alternates in a number of specific services. Advantages for this type of installation include: (1) a better tubeside film coefficient, (2) an opportunity to suppress vaporization by control of tubeside pressure, (3) a reduction in the tubeside film temperature due to increased turbulence, and (4) the scouring action of the high velocity fluid in the tubes. Certain extra expenses are involved in high velocity forced circulation. The major contribution to higher expense is the pumping cost, which includes amortization of the initial investment, and the power and maintenance expense. The cost of the pumping installation is high due to the high temperature and possibly abrasive service and the high-head, high capacity requirement. This higher cost is offset by a reduced investment for heat transfer surface.

It is not the intention to recommend a general shift to high tube velocity reboilers. In most services thermosiphon or natural convection reboilers prove more economical in the long run. An honest appraisal is required in the selection of the type of installation.

On the assumption that a high-velocity forced-circulation exchanger is indicated, a definition of the parameters involved in the optimum design is necessary. The rest of this article is limited in scope to this type. The major design criteria are discussed, an economic balance approach to optimum design is submitted, some successful applications are reviewed, and a sample design is included to clarify the presentation.

Design parameters

Figure 1 is an example of the type of installation in which a high-velocity forced-circulation reboiler is utilized. This diagrammatic flow sheet illustrates the major equipment required. The primary design effort is aimed at the optimum physical design of the heat exchanger internals. The pump is designed to furnish the relatively high head and high capacity required to obtain the tube velocities desired. The pressure controller is added to suppress or eliminate vaporization by control of pressure in the exchanger tubes. The strainer installation is sometimes necessary for a rough screening elimination of coarse particles.

Knowledge of the relation between tube velocity and fouling is necessary before any definitive design effort can be started. Pilot testing is the only sure method for determining this information. Plant tests have been devised to obtain applicable data for the design of nearly all of our new installations. Revision or replacement of the existing bottoms pump plus blanking a portion of the tube sheets in the existing reboiler permits test operation at increased tube velocity. Further revisions are required to obtain data at other velocities. Pump curves are used to determine circulation rates. A check on the circulation rate can be made from the heat balance and the temperature rise through the exchanger.

Owing to the one to four weeks required to measure the fouling rate variation at each tube velocity the number of velocities studied is usually limited to two or three. The rate of change in fouling rate is extrapolated to provide the design information. Estimation of the specific tubeside fouling resistance provides the most accurate criterion for extrapolation. Evaluation at the fouled condition is necessary to verify the design conclusions.

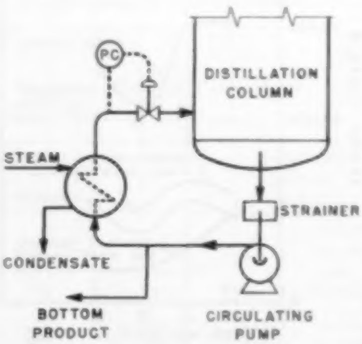

Figure 1. High-velocity forced-circulation reboiler layout

Often the operation under test conditions permits rates approaching normal and extensive testing can be done without incurring large production losses or excessive expense.

The measure of fouling is estimated on the basis of the experimentally determined over-all heat transfer coefficient. As the velocity through the tubes is increased, the clean coefficient increases owing to the higher tubeside film coefficient. However, this improvement is insignificant compared to the reduction in the fouling rate as higher velocities are used. Usually significant reduction in fouling occurs at rates above 8 ft./sec., and at higher rates the resistance due to fouling is reduced to the point where other resistances in the system become controlling. Forced circulation at rates below 5 ft./sec. generally fails to exhibit any advantage in fouling service.

The application of the high-velocity principle appears beneficial regardless of the type of heavy fouling. Two types of rapid fouling have been involved in most of the designs considered. The more prevalent has been the fouling which occurs as a result of vaporization at the tube walls. The scale is caused by either solid deposition or polymerization of the heavier ingredients concentrated near the surface. The other type has been the scaling of a similar nature which results from polymerization or coke formation at the surface caused by high tubeside film temperature. The normal fouling rate due to impingement or tube plugging is greatly increased because of the roughness and sticky nature of the film.

Operation at high velocity has the advantage of minimizing these types of fouling. As the forced circulation rate increases, the per cent vaporization per pass is lowered, thus reducing the deposit on the walls. If all the heat can be introduced as sensible heat in the process stream with pressure control, vaporization is eliminated. Also, the temperature difference between the tubeside film and the bulk of the process stream decreases as the turbulence increases and

Reboilers

continued

localized reaction at the surface is minimized. With these heavy fouling mechanisms controlled, the normal impingement fouling rate becomes slower. In some cases with suspended solids a definite scouring action occurs and the fouling rate is further reduced.

Considerable latitude is available in the design of the exchanger. The heat transfer surface requirement is selected on the basis of the over-all coefficient which varies as a function of the tube velocity. The tube velocity is set by the capacity of the circulating pump, the tube length, and the number of passes. The head requirement of the pump varies with the tube velocity. The optimum design can be established only by an economic balance which includes operating expense as well as amortization of the initial investment.

Two standard rules of heat exchanger design must be ignored in the design of high-velocity reboilers. First, velocities above 5 ft./sec. have normally been avoided due to the threat of erosion. In our installations velocities up to 30 ft./sec. have been used and maintenance expense due to erosion has been negligible. Second, tubeside pressure drops above 10 lb./sq. in. have normally been avoided. In several high-velocity forced-circulation systems pressure drops above 60 lb./sq. in. have been necessary to obtain tube velocities at which the turbulence level minimizes tube film temperature.

The return line from the reboiler to the column can be sized to control the pressure in the tubes above the vaporization pressure. However, greater flexibility is obtained by adding instrumentation for pressure control. The limitation on per cent vaporization required to minimize fouling can be defined only by pilot tests. Where possible, complete suppression of vaporization is recommended.

Increasing the number of tube passes by head revisions has the potentiality of doubling or quadrupling the tube velocity. As long as the fouling is of the type caused by overheating or vaporization at the tube wall, adding tube passes shows advantage. Where the process stream contains suspended solids, deposition at the return bends may reduce the advantage of higher tube velocity. High tube velocity can also be obtained by using smaller tubes and maximum tube length. The design of forced-circulation reboilers assumes cleanout at least on a yearly basis and ¾-in. tubes have been standardized as a minimum for mechanical cleaning.

Horizontal reboilers are used, except where space limitations dictate an alternate choice. Location of the exchanger to minimize pipe lengths is a consideration when the high circulation rate is considered.

The installation of strainers in the circulation pump suction line is recommended in services in which the process stream contains suspended solids. Low pressure drop basket-type strainers with the mesh sized to remove only large fragments have proved adequate. In several services the strainers have been by-passed except during start-ups.

Sample design by economic balance

Consideration of all the significant incremental costs which are involved in the operation of the forced-circulation reboiler is necessary to predict the optimum design. These usually include amortization of capital for the reboiler exchanger and the pump and motor, and expenses for reboiler maintenance, pump and motor maintenance, and power costs.

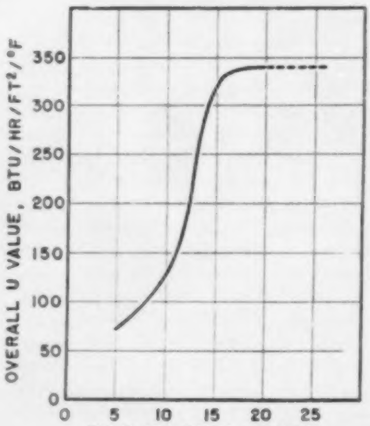

Figure 2. Variation of fouled heat transfer coefficient with tube velocity

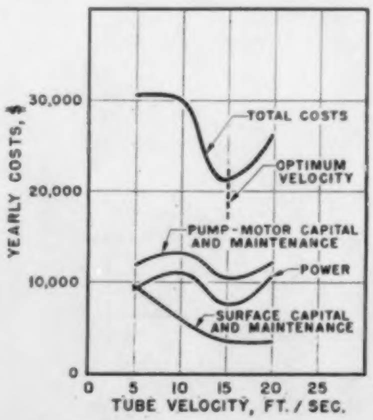

Figure 3. Determination of optimum tube velocity by economic balance

The procedure is best illustrated by the solution of a hypothetical problem, such as the following one:

A dilute aqueous solution of salt and polymer (physical properties taken as those of water) is to be heated on the tubeside with 50-lb. steam as the heating medium. A process pressure of 1 atm. and a heat load of 10 million B.t.u./hr. are assumed.

The first step in the calculation is to estimate the over-all heat transfer coefficient at several tubeside velocities. As stated previously these data must be determined experimentally by pilot testing with the specific process stream. Normally the pilot data are obtained in a similar but not a duplicate system. Calculations are made to estimate the contribution of the fouling resistance in the pilot test case and to apply this factor in the estimate of the design coefficients. In either case a plot of the variation of the over-all heat transfer coefficient vs. tube velocity such as the one shown in Figure 2 is obtained. This curve illustrates the typical variation of the coefficient (obtained in a unit after a fixed period of operation at each condition) with respect to tube velocity. Fouling would be more rapid at tube velocities below 5 ft./sec. due to vaporization on the tube walls and a higher temperature in the liquid film. As the tube velocity increases, the over-all coefficient improves until the resistance due to fouling is reduced to the level of the other resistances to heat transfer. For this problem the effect of fouling is practically eliminated at a tube velocity of 20 ft./sec.

The corresponding process side fouling factors calculated for this sample vary from 0.01 at 5 to 0.001 at 15 ft./sec. For comparison the total heat transfer resistances are 0.014 at 5 and 0.003 at 15 ft./sec. By increasing the turbulence in the tubes the contribution of fouling to the total resistance is reduced from 70 to 35% over the range of tube velocities tested.

The next step in the design calculations is to estimate, using the coefficients as presented in Figure 2, the reboiler surface requirement and the total circulation rate at several velocities. While the total heat load is fixed, this calculation involves a trial-and-error technique to obtain a precise solution. The temperature of the process stream leaving the reboiler can be

calculated if the total circulation rate is known, but the circulation required to attain a designated tube velocity depends on the number of tubes which is in turn a function of the total surface requirement. Since the temperature difference between the heating medium and the inlet process temperature is usually very large, the effect of the temperature rise in the process stream can be neglected as a first approximation and only a small correction is required to obtain the final solution. For simplicity a single tube pass with 1-in. by 8-ft. tubes was selected for each of the cases in the sample design; therefore, the tube velocity is only a function of the total circulation and the number of tubes. Selected results obtained in the sample calculation are shown in the first two columns of Table 1. It should be noted that the circulation rate passes through a minimum as mentioned previously.

Pressure drop calculations are then made to provide data for sizing the circulating pump and driver. Results of these are also summarized in Table 1. Then, estimates of the installed capital costs for the reboiler and for the pumping installations are made for each of the cases considered. The cost estimate for the reboiler is for the exchanger alone. The estimate for the pumping installation includes the cost of a spare pump, the drive motors, and facilities for delivering power to the drivers as well as the installed cost of piping and control instrumentation. Typical installed costs vary with tube velocity (see Table 1).

To compare the cases under consideration on a total annual expense basis for a determination of the optimum installation, a two-year amortization rate was selected for the installed capital costs. The variation and relative magnitude of these annual expenses are depicted in Figure 3. For the purposes of this illustration the reboiler maintenance was estimated as 10% of the installed cost and the pump maintenance was estimated as a fixed expense of $2,000/yr.

The variation in the total annual expense on this basis with respect to the design tube velocity is also shown in Figure 3. As demonstrated, the lowest annual expense estimate is obtained with the installation designed for a tube velocity of 15 ft./sec. It should be noted that selection of a longer amortization period for the installed capital would significantly reduce the magnitude of the total annual expense but would not appreciably affect the optimum solution.

Shell Chemical applications

A number of high-velocity forced-circulation reboilers are in operation in extremely fouling services within the Shell Chemical plants. A description of the development of two successful applications of the design principle follows:

1. *A minimum investment revision to improve an existing installation.* An existing 300 sq. ft. single-pass horizontal reboiler in heavy organic chlorides service was a production bottleneck and a source of high-maintenance expense due to rapid fouling. A shutdown was required every 20 to 25 days for cleanouts and approximately one day's production was lost per shutdown. In more technical terms, the calculated over-all heat transfer coefficient was reduced from 130 B.t.u./(hr.)(sq. ft.) (°F.) after cleaning to a value of 50 after 3 weeks. The rapid fouling was caused by a gradual build-up of carbonaceous solids deposited as the result of vaporization and not removed from the tubes because of the adherent characteristics of the coke. The low tube velocity—3-4 ft./sec.—was not adequate to sweep the particles from the exchanger.

Fouling data at higher velocities for the particular process stream were available from two smaller reboilers in operation in similar service. On a development test basis, 40% of the tubes were blanked off and the existing circulation pump was replaced by one with double the original capacity. In addition provision was made to control the downstream pressure to eliminate vaporization in the tubes. A service coefficient of 160 B.t.u./(hr.) (sq. ft.) (°F.) at a tube velocity of 15 ft./sec. was predicted for the revised facilities. In operation the over-all coefficient varied from greater than 250 after cleaning to 100 after four to six months in service. Full-rate production was maintained and a 3% increase in the stream factor of the unit resulted. Consequently, the installation was made permanent, and additional units in similar services have been designed for these conditions.

2. *A necessary replacement for a deteriorated internal heating coil in a large vacuum evaporator handling a heavy organic-salt slurry.* The internal heating coil was supplemented with a small external forced-circulation reboiler. Replacement of the internal coil would have required complex revisions to the alloy evaporator at considerable expense. The substitution of one large forced-circulation external reboiler for both existing exchangers was considered. Since the external surface requirements would be excessive if the design were based on the average over-all coefficient of 50 B.t.u./(hr.) (sq. ft.) (°F.) experienced in the existing external reboiler, a test using *higher* tube velocities was initiated. It was possible to increase the tube velocity from 1-4 ft./sec. (without revising the circulating pump) by merely reducing the number of tubes in service from 318 to 70. As a result of this change the average over-all coefficient was increased to 165, and 80% of the normal heat duty was obtained. It was assumed that a comparable coefficient could be obtained in the proposed reboiler if the same level of tube turbulence, as measured by the calculated Reynolds number, were maintained. A brief economic study indicated that pumping costs would overshadow the possible reduction in reboiler surface cost at tube velocities above 8 ft./sec. Therefore, the new unit was designed for a tube velocity of 8 ft./sec. with a predicted coefficient of 150, and a significant saving, compared with the estimated replacement cost for the internal coil, was achieved. The new installation has met design conditions in satisfactory operation.

Presented at 1958 A.I.Ch.E.-A.S.M.E. Heat Transfer Symposium, Chicago, Ill.

Table 1.—Summary of Reboiler Economic Balance Calculations
Sample Design Case

Tube velocity ft./sec.	Required exchanger surface, sq.ft.	Required pump capacity gal./min.	Pump head lb./sq.in.	Motor hp.	Power consumption, kw.	Installed capital cost, $: Reboiler	Installed capital cost, $: Pump, spare and motors
5	1,660	6,700	30.7	170	230	16,000	19,500
10	930	7,500	32.8	200	270	10,000	22,000
15	348	4,200	36.2	135	182	6,000	16,500
20	342	5,550	41.0	185	250	6,000	20,000

Boiling burnout with water in vortex flow

Preliminary study of boiling burnout heat fluxes associated with forced-convection flow of water through small diameter tubes indicates that large heat fluxes are easily obtainable.

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Modern high-performance devices such as nuclear reactors and rocket motors can be operated with large heat fluxes and power densities. These are essentially constant heat-input systems, with the heat flux imposed independently of coolant thermal resistance. If cooling is inadequate, a rapid fusion failure or "burnout" of the heat-transfer surface ensues. This situation has prompted considerable investigation of the boiling burnout process for the common case of linear coolant flow; much of this information has been summarized by Bonilla *(1)*.

The present study evolved from one begun earlier on heat transfer to air and nonboiling water in vortex flow. The change of emphasis was motivated by the concept that the large radial contrast of fluid density associated with boiling systems might combine with the centrifugal acceleration arising from a rotating flow so as to establish a significant inward radial transport of steam bubbles. In this event, the inner surface would be freer of bubbles (lower fractional coverage) at a given heat flux. The maximum or burnout flux, which is believed to occur at some critical boundary-layer quality, would accordingly be larger. It was therefore decided to conduct, as simply as possible, a preliminary study of the gross variables of such a system.

Potential applications of vortex boiling might include: cooling of particle accelerator targets, application to high-power-density nuclear reactors, cooling of liquid-propellant rocket motor nozzle throats, and possible use in some atmospheric re-entry situations.

† *Operated by Union Carbide for AEC.*

Prior work in this area apparently has been limited. A number of studies of fluid flow without heat transfer in vortex tubes of the Ranque-Hilsch type have been published; the latest include the detailed experimental programs of Hartnett and Eckert *(2)*, Scheller and Brown *(3)*, and Lay *(4)*. Recent theoretical analyses of rotating fluid flows have been published by Yeh *(5)*, Kuo *(6)*, and Deissler and Perlmutter *(7)*. A few studies *(8, e. g.)* have dealt with low flux heat transfer across annular air gaps with one or both boundary cylinders rotating, in simulation of rotating electrical machinery. Jakob *(9)* has summarized results for natural-convection internal liquid cooling of rotating gas-turbine blades. The influence of wall curvature on fluid flow has been investigated by Eskinazi and Yeh *(10)* and on heat transfer by Kreith *(11, 12)*. A recent paper by Kreith and Margolis *(13)* gives results for heat transfer and friction with swirling turbulent flow of air and nonboiling water. Swirl was induced by twisted strips (and coiled wires), and it was found that at high Reynolds numbers, the heat transfer for a given pumping power was greater than for linear flow at the same rate in an empty tube. Siegel and Perlmutter *(14)* have reported theoretically calculated results for heat transfer to laminar vortex flows.

Near the end of the experimental program, the authors learned of two other preliminary investigations of boiling with whirling flow *(15, 16)*. In these brief unpublished studies, experimental conditions were milder than those reported here, and the observed burnout heat fluxes at equal pumping power were increased above those for linear flow by $< 20\%$. This result is in qualitative agreement with the data of the present paper for the range of low pumping power. Early results of the present study were reported in two Oak Ridge National Laboratory memoranda *(17, 18)*, in a brief technical note *(19)*, and at the Second National Heat Transfer Conference *(20)*.

Apparatus and procedure

A schematic diagram of the experimental system is shown in Figure 1. Terminal water temperatures were measured with calibrated chromel-alumel thermocouples connected to a strip-chart recording potentiometer with icebath cold junction. These water temperatures were periodically verified several times in each test and as close to the burnout point as possible with calibrated mercury-in-glass thermometers. Heat input from the pumps was important in some tests, and inlet water temperature was always measured after a period of steady-state pump operation without test-section heating.

Test-section outer wall temperatures were measured in some tests with 36-gauge calibrated chromel-alumel thermocouples spot-welded to the outer surface and wound circumferentially for a short distance; these were printed on a multipoint recorder. The test section was generally left

bare when burnout points only were being determined but was insulated with asbestos tape when wall temperatures were measured.

Voltage impressed across the copper electrodes was measured with a precision vacuum-tube voltmeter. Calculations indicated that heat loss by convection and radiation from a bare tube to the atmosphere and by axial conduction to the electrodes was generally only of the order of ½% of total heat generation. Consequently, all burnout heat fluxes were calculated from water heat absorption rate and cold test-section dimensions.

The rotameters were directly calibrated over the full range of use with a large calibrated weigh tank and stopwatch. All static pressures were measured with new Bourdon-type gauges. As designated in Figure 1, pressure P_1 was measured at the discharge of the booster pump, which was a progressive-cavity (Moyno) type in some tests and a gear type in other tests. Pressure P_2 was measured at the test-section inlet in all cases. With the spiral-ramp vortex generator (Figure 2), the pressure tap was located halfway along the length of the tapered orifice (0.115-in. inlet to 0.093-in. exit), where the orifice diameter was 0.104 in. Test-section exit wall pressure P_3 was measured for three vortex tests by means of a 0.021-in. diam. hole drilled through the downstream electrode and the tube wall.

Entrance regions used are depicted in Figure 2. The spiral ramp vortex generator, made of chrome-plated brass, was taken from a commercial Hilsch tube. A convergent cone transition section served to join generator and test sections and also to accelerate water rotation rate by conservation of angular momentum. Three to four tube diameters separated inlet orifice and initial heated portion of the test section. The same spiral-ramp generator was used in all tests given in Table 1.

A typical tangential-slot vortex generator and test section are also shown in Figure 2. The slot dimensions of all such generators used in this study were 0.031 in. by 0.100 in.; the number of slots was two, four, or eight. In test No. 21 (Table 2), a larger copper vortex generator from test No. 20 was mated to the smaller diameter molybdenum tube by building up a convergent cone of silver solder to a diameter of 0.191 in. at the exit of the vortex generator. In tests 11 and 12 of Table 2, a small (0.050-in. diam.) "spike" was attached to the upstream closure cap and centered in the entrance region, but this was omitted from all subsequent tangential-slot test sections.

The first comparative straight-flow tests were made with straight, unaltered test-section inlets, but entrance region instability and apparent boundary-layer separation necessitated use of the convergent-cone entrance regions, as shown in Figure 2. These seemed to perform stably.

In some of the spiral-ramp vortex tests, test sections with tapered walls were used in an attempt to utilize the greater circulation of the freshly formed vortex by generating heat at a greater rate at the inlet and reducing heat generation with length to qualitatively match the decreasing flow vorticity. Such variation of heat generation rate with length is obtainable in a nuclear reactor by selective fuel placement.

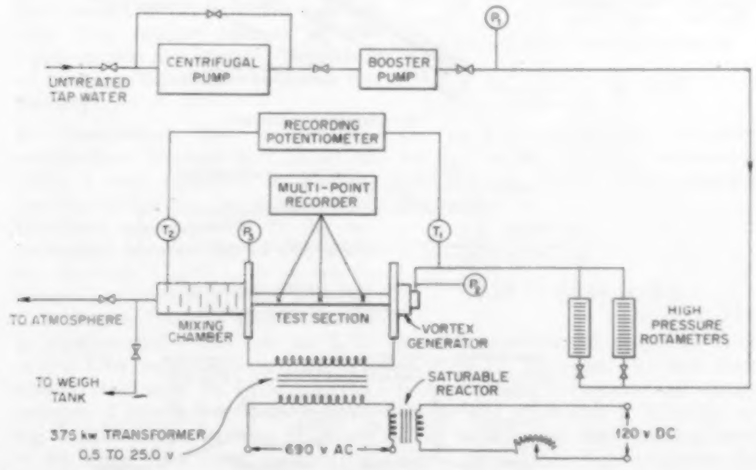

Figure 1. Experimental heat-transfer apparatus.

All test sections were horizontal and heating was with 60-cycle a.-c. throughout. The coolant water was not distilled, degassed, or deionized and apparently contained a considerable amount of air. Burnout was attained in all cases by slowly increasing heat generation at constant flow rate. No electronic burnout-protection circuits were used, and burnout occurred in a thin annular ring at the test-section exit in all tabulated tests. Test-sections were connected to the ¼ to ½-in. thick copper electrodes with high-temperature silver solder. The necessity of balancing the opposing requirements of very high heat flux, minimum thermal stress, and limited available voltage restricted the test sections to thin wall, short tubes.

Test results, calculation

Results for the spiral-ramp burnout tests are summarized in Table 1, and for tangential-slot burnouts in Table 2. A number of tests for low-pressure water in straight flow were also made for comparison purposes; these are given in Table 3. In each table $(P_f/P_q)\%$ represents pumping power across the test section as a percentage of heat extraction rate at the burnout point, as calculated from

$$P_f = \frac{W \Delta P}{13{,}750\ \rho} \qquad (1)$$

$$P_q = \frac{q_b}{2{,}545} \qquad (2)$$

$$\text{and } (P_f/P_q)\% = \frac{100\ P_f}{P_q} \qquad (3)$$

In all cases, the total pressure at the test-section inlet was used for ΔP. This assumes total head loss with no pressure recovery at exit and represents the most unfavorable condition. High-efficiency diffusers for velocity-pressure transformation of rotating flows have been investigated, however *(21)*. For vortex tests with the spiral-ramp generator, the velocity head at the orifice pressure tap was added to the gauge reading; but with the other entrance regions, approach velocity in the outer concentric pipe was small enough not to require velocity head addition.

Superficial axial velocities in Table 1 correspond to the density at the exit temperature. The "bulk subcooling at exit" of Table 1 was taken at saturation temperature at exit pressure,

continued

Boiling burnout

continued

minus bulk exit water temperature. Estimation of the actual local degree of subcooling at the exit wall is given in Appendix II.

Net steam was generated only in vortex tests 1 and 2; for these tests, exit quality was calculated from:

$$x = \frac{q_{\text{latent}}/L_v}{W} \times 100 \qquad (4)$$

where

$$q_{\text{latent}} = q_{\text{total}} - q_{\text{sensible}}$$

and

$$q_{\text{sensible}} = W\, C_p\, dt$$

The burnout flux and q_{total} of Equation (4) were determined by first running just below the point of net steam generation and calculating the heat absorption at this lower reference level from $q_R = W\, C_p\, dt$. For constant test-section resistance, power dissipation is proportional to the square of impressed voltage; accordingly:

$$(q_{\text{total}})_b = q_R \left(\frac{E_b}{E_R}\right)^2 \qquad (5)$$

Calculations indicate that the small increase of tube-wall temperature caused by the power level increase from q_R to q_b was negligible in its influence on both heat loss and test-section electrical conductivity.

A review of the calibration errors indicates a maximum error in the reported burnout heat fluxes of $\pm 5\%$ and a probable error of $\pm 2\%$. The range of experimental variables is given in Table 4.

In earlier reports of this work *(17–20)*, burnout heat fluxes for the tests in which tapered tubes were used were calculated as the ratio of total heat absorption rate to total internal area. This procedure, however, gives an over-all value for the entire tube which is larger than the burnout heat flux at the tube exit, where burnout actually took place. All burnout values for the tapered-tube tests have accordingly been corrected to the exit by multiplying the over-all burnout heat flux as defined above by the ratio of mean to exit electrical cross-sectional areas.

Discussion

The goals originally defined for the experimental program were:

(a) To determine the absolute magnitude of burnout heat flux attainable with a reasonable pumping system. This is of interest in applications to particle-accelerator target cooling, where potential heat fluxes would be very high, target tubes small, and pumping power relatively unimportant.

(b) To devise an approximate correlation by which estimates of burnout flux could be made.

(c) To compare vortex and straight-flow boiling on the basis of heat transfer at burnout with constant pumping power. This would be of importance in nuclear power reactor applications.

The discussion will deal with each of these points in turn, as well as with certain secondary information which was derived.

A. Magnitude. The burnout heat flux of 54.8×10^6 B.t.u./(hr.) (sq. ft.) attained in vortex test No. 21 is, to the knowledge of the authors, the largest ever reported for any coolant in any geometry. The volumetric heat release rate or power density within the test-section wall was 3,680 kw./cc. (355×10^9 B.t.u./(hr.)(cu. ft.). A brief compilation indicating the broad range of heat fluxes encountered in modern industrial and scientific practice is given in Table 5 for orientation. In considering absolute magnitudes of heat flux, one must distinguish between generated or input fluxes and those actually transferred to a coolant, and between steady-state and transient heat fluxes. In shock tubes, e.g., enormous heat fluxes may be generated for brief periods, but the heat is not transferred to a coolant.

Vortex test No. 12, in which the burnout flux was 35.1×10^6 B.t.u./(hr.)(sq.ft.), will be discussed at greater length since more data were obtained for this test. Conditions at burnout were generally extreme since the material (Inconel) has a small thermal conductivity. The entire exterior tube surface reached a state of bright redness some time before burnout. The wall temperature difference, Δt_W, for conditions of uniform heat generation and zero external heat loss, may be calculated from the following simplified form of the Kreith-Summerfield relation *(22)*, as also used by Bernardo and Eian *(23)*:

$$\Delta t_W = \frac{(q/V_h)}{2k}\left[R_2^2 \ln\left(\frac{R_2}{R_1}\right) - \frac{R_2^2 - R_1^2}{2}\right] \qquad (6)$$

For vortex test No. 12, Δt_W was 1,330°F., corresponding to a radial wall thermal gradient of 133,000°F./

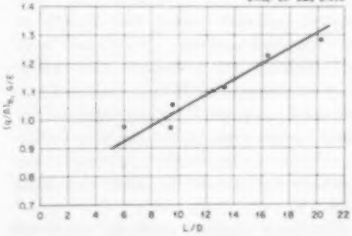

Figure 3. Correlation of straight-flow burnout data.

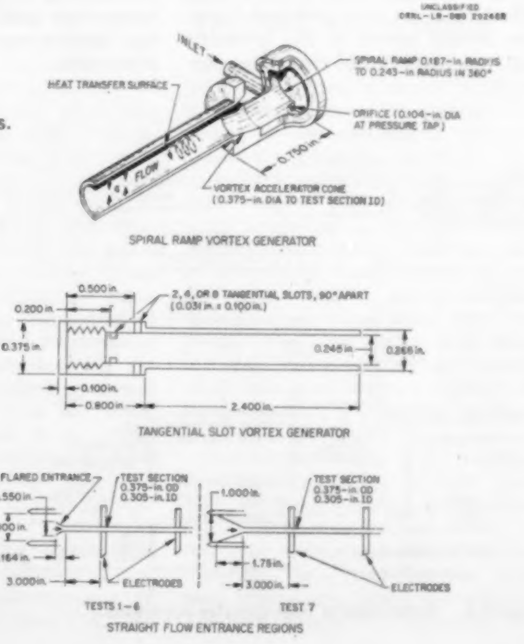

Figure 2. Test sections.

in. The controlling thermal stress for the geometry under consideration is the tangential or circumferential stress at the inner wall; this was calculated from the following expression *(24)*:

$$\sigma_{ttt} = \frac{E\alpha\,(q/V_h)\,R_2^2}{4k\,(1-\upsilon)\,(R_2^2-R_1^2)} \left[\frac{R_2^4}{R_2^2-R_1^2}\ln\left(\frac{R_2}{R_1}\right)^2 - R_2^2 - \frac{R_2^2-R_1^2}{2}\right] \qquad (7)$$

to be 2.06×10^6 lb./sq. in. (elastic thermal stress), which shows that the Inconel was well beyond the elastic limit and in the region of plastic behavior. Four photomicrographs of the tube wall for vortex test No. 12 indicated nothing abnormal in the Inconel structure, however.

An estimate was also made for vortex test No. 12 of the amplitude of the sinusoidally varying temperature at each surface of the test section. A complicated relationship for accomplishing this has been published in a University of California report *(25)*. The equation, too lengthy to conveniently reproduce here, was derived for a flat plate insulated on one side and for uniform and constant thermal and electrical properties. Properties of the tube were taken in the present estimate at arithmetic average wall temperature, and the flat plate condition is approximately fulfilled since the mean radius to wall thickness ratio was 12.75. The calculation indicates that the amplitude of outer wall temperature (at a frequency of 120 c/s) was 180°F., and of inner wall temperature, 51°F. This causes thermal cycling of tube metal already subjected to severe conditions and would be expected to cause earlier burnout than d.-c. heating because of the ripple in heat flux (roughly estimated to be $\backsim \pm 38\%$ about the mean for this test).

B. Correlation. The comparative straight-flow burnout heat fluxes of Table 3 were correlated by plotting the ratio of burnout flux predicted by Gunther's equation *(26)* to the experimental burnout flux of this study vs. the ratio (L_h/D_1), as shown in Figure 3, where the ordinate subscript G/E denotes "ratio of Gunther value to experimental value." At an L/D of 6.0 (the length to equivalent diameter ratio used by Gunther), the ordinate of Figure 3 is 0.924, indicating that the present burnout fluxes are $\sim 8\%$ larger than those reported by Gunther for the same conditions. The straight line of Figure 3 may be represented by the equation:

$$(q/A_1)_b = \frac{7000\,V^{1/2}\,(\Delta_{t\ sub})\text{exit}}{0.76 + 0.02735\,(L_h/D_1)} \qquad (8)$$

which represents the limited data of Table 3 within average and maximum errors of 2.6 and 5.2%. The denominator of Equation (8) also extends applicability of the original Gunther equation (for $L/D_e = 6.0$) to an L/D of 20.

Vortex boiling burnout heat fluxes were correlated empirically by first plotting $(q/A)_b$ vs. L/D for tests of equal V_{ax}. The mean curve through these points was then replotted as

$$\frac{(q/A)_b,\ L/D=x}{(q/A)_b,\ L/D=6} \text{ vs. } L/D;$$

i.e., an L/D of 6.0 was arbitrarily selected as the value for which this heat flux ratio is unity. This procedure resulted in:

$$\frac{(q/A)_b,\ L/D=x}{(q/A)_b,\ L/D=6} = 1.29 - 0.049\,(L/D) \qquad (9)$$

for the experimental range of L/D = 2 to 12. Equation (9) was then used to "correct" experimental values of $(q/A)_b$ at various L/D ratios to L/D = 6.0, and the resulting heat fluxes plotted vs. V_{ax}, as shown in Figure 4. This simple procedure appears to correlate the vortex burnout heat fluxes well within the data spread encountered with most straight-flow burnout relations, and works better than a number of other more sophisticated approaches which were also tried. The heavy line (No. 1) of Figure 4, representing the over-all data collection, may be represented by:

$$(q/A_1)_b = [359{,}700\,V_{ax} + 7.10 \times 10^6]\,[1.29 - 0.049\,(L/D)] \qquad (10)$$

Equation (10) exhibits average and maximum errors for the over-all data of 12.5% and 32.4%; for the spiral-ramp data, 12.0% and 24.3%; and for the tangential-slot data, 13.0% and 32.4%. Figure 5 is a plot of Equation (10) for the range of V_{ax} and L/D of the tests.

For the spiral-ramp vortex tests only (curve 2), the best equation is:

$$(q/A_1)_b = [590{,}000\,V_{ax} + 2.48 \times 10^6]\,[1.29 - 0.049\,(L/D)] \qquad (11)$$

with average and maximum errors of 7.5 and 17.5%.

The tangential-slot vortex burnout data are best represented by the separate curves 3 and 4 of Figure 4, on the basis of internal surface roughness. The burnout fluxes for the rougher tubes (35-60 μin. rms) are apparently 30 to 45% larger than those for the very smooth tubes (7-15 μin. rms), which qualitatively agree with accepted theories of the interaction of nucleate boiling and surface condition. The equation best representing all the tangential-slot data, without regard to surface roughness, is:

$$(q/A_1)_b = [239{,}000\,V_{ax} + 13.80 \times 10^6]\,[1.29 - 0.049\,(L/D)] \qquad (12)$$

with average and maximum errors of 14.4 and 21.8%.

In straight-flow boiling burnout, degree of subcooling is an important variable, but such does not appear to be the case in vortex boiling, as shown in Figure 6. If the values of V_{ax} and L/D were identical for the three points of Figure 6, the point at the right would be somewhat lower and the line would be essentially horizontal, indicating zero dependence of burnout heat flux on degree of bulk subcooling. This is interpreted to mean that the centrifugal acceleration associated with vortex flow is indeed effective in displacing nascent steam bubbles from the wall toward the tube centerline, and that bubble condensation takes place off the wall.

continued

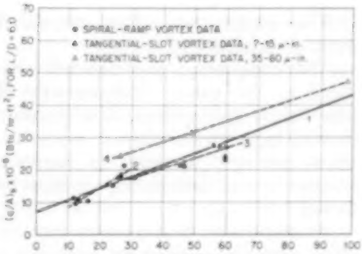

Figure 4. Vortex heat fluxes plotted vs. v_{ax} for L/D = 6.0.

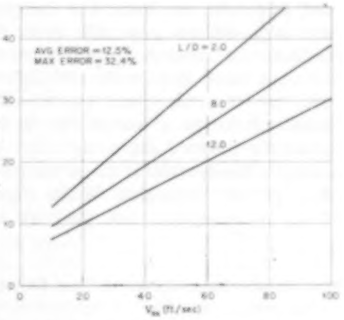

Figure 5. Correlation of all vortex burnout data [plot of Eq. 10]

Boiling burnout

continued

In this event, Δt_{sub} could not be an influential factor, since the burnout process depends only on local conditions at the wall.

C. Comparison with straight-flow burnout. In Figure 7, burnout fluxes for linear flow as predicted by the correlations of Gunther *(26)* and of McGill-Sibbitt *(27)*, are plotted vs. velocity with degree of exit subcooling as a parameter. The McGill-Sibbitt correlation:

$$(q/A)_b = 246{,}000\ V^{1/2}\ (\Delta t_{sub})^{0.28} \qquad (13)$$

is based on data from a tube of $L/D = 21$, and values calculated from Equation (13) were approximately corrected to $L/D = 6$ by the rule-of-thumb that halving L/D increases $(q/A)_b$ by $\sim$ 15%.

The vortex curve was calculated from Equation (10).

The comparison is somewhat artificial to the extent that for any of the linear flow curves, exit pressure would have to be altered when velocity changes in order to maintain degree of exit subcooling constant as noted.

In Figure 8, heat-transfer rate vs. flow power is plotted for both linear and vortex flows in a given tube at the burnout point. For details concerning the construction of Figure 8, see Appendix I. Since the comparison is based on a specific tube, the ordinate is directly proportional to burnout heat flux, with 100 hp. = 28.7×10^6 B.t.u./(hr.) (sq.ft.). The small advantage of vortex flow at low pumping power [also noted *(15)*] becomes considerable at large values of flow power dissipation. While Figure 8 is, of necessity, not general, the results are considered to be typical.

Another comparison based on local conditions at the exit tube wall is given in Appendix II. This comparison, although limited in range, indicates that vortex boiling burnout heat fluxes are relatively independent of true local degree of subcooling at the wall as well as the "bulk degree of subcooling" previously defined.

D. Variation of heat-transfer coefficient. Local and over-all heat-transfer coefficients and their variation with heat flux have been calculated for vortex test No. 8 only. Thermocouples were located on the test-section exterior surface at distances of 0.25, 1.17, and 2.08 in. from $L_h = 0$. Equation (6) was used in conjunction with a graphical procedure (see Appendix III for details) to calculate the coefficients. At the vertical line of Figure 9, boiling just begins at the exit, using calculated inner wall tempera-

Table 1. Spiral-ramp Vortex Boiling Burnout Tests

Test No.	Superficial axial velocity ft./sec.	Bulk sub-cooling at exit °F.	Inlet static pressure lb./sq. in. gauge	Test section: I.D. in.	O.D. in.	Heated length in.	L_h/D_i	Material	x, Exit quality %	$\left(\frac{P_f}{P_e}\right)^*$ %	Exptl. $(q/A_i)_b$ B.t.u./(hr.)(sq. ft.)**
1	11.80	0	94	0.275	0.300	3.187	11.60	Copper	1.24	0.28	8.2×10^6
2	12.35	0	99	0.275	Inlet 0.288 Exit 0.300	2.875	10.44	Copper	1.49	0.30	7.3×10^6
3	13.61	72	100	0.250	0.300	1.20	4.80	Inconel	0.0	0.60	11.0×10^6
4	13.18	135	248	0.300	0.375	3.05	10.16	Copper	0.0	0.48	8.6×10^6
5	16.30	150‡	248	0.250	Inlet 0.270 Exit 0.281	2.25	9.00	Inconel	0.0	0.48	8.9×10^6
6	24.00	49	285	0.250	Inlet 0.270 Exit 0.278	1.625	6.50	Inconel	0.0	1.45	14.6×10^6
7	26.40	17	415	0.275	Inlet 0.302 Exit 0.315	3.30	12.00	"A" Nickel	0.0	1.37	13.1×10^6
8	26.40	51	371	0.275	Inlet 0.305 Exit 0.314	2.33	8.46	"A" Nickel	0.0	1.63	15.2×10^6
9	25.80	87	365	0.275	Inlet 0.305 Exit 0.310	1.30	4.73	"A" Nickel	0.0	2.58	18.6×10^6
10	27.50	118	400	0.275	Inlet 0.305 Exit 0.307	0.54	1.96	"A" Nickel	0.0	5.33	25.5×10^6

* *Calculated for burnout condition, using total head loss for flow-work term P_f.*
** *Corrected to tube exit for tapered-wall test sections.*
‡ *Exit held at 100 lb./sq. in. gauge. Atmospheric discharge in all other tests.*

Table 2. Tangential-slot Vortex Boiling Burnout Tests

Test No.*	Superficial axial velocity ft./sec.	Bulk sub-cooling at exit** °F.	Inlet static pressure lb./sq. in. gauge	Test section: I.D. in.	O.D. in.	Heated length in.	L_h/D_i	Material	No. of generator slots‡	Roughness‡‡ micro-inch rms	P_f HP	$\left(\frac{P_f}{P_e}\right)$ %	Exptl. $(q/A_i)_b$ B.t.u./(hr.)(sq.ft.)
11	26.4	28	495	0.245	0.265	1.87	7.63	Inconel	2	35	1.11	1.25	22.6×10^6
12	48.9	104	540	0.245	0.265	0.90	3.67	Inconel	4	37	2.25	3.39	35.1×10^6
13	57.8	97	410	0.250	0.270	1.88	7.52	"A" Nickel	8	10	2.11	2.08	25.2×10^6
14	59.4	125	340	0.250	0.270	1.00	4.00	"A" Nickel	8	10	1.80	3.20	26.2×10^6
15	45.1	92	560	0.250	0.270	1.88	7.52	"A" Nickel	4	10	2.25	2.86	19.6×10^6
16	55.8	110	930	0.250	0.270	0.914	3.66	"A" Nickel	4	10	4.61	7.69	30.8×10^6
17	31.0	75	800	0.250	0.272	1.86	7.44	"A" Nickel	2	7	2.20	3.39	16.3×10^6
18	59.8	100	385	0.250	0.271	1.88	7.52	"A" Nickel	8	10	2.04	2.39	21.3×10^6
19	59.8	112	338	0.250	0.271	1.00	4.00	"A" Nickel	8	10	1.80	2.84	29.6×10^6
20	46.6	87	532	0.250	0.271	1.90	7.60	Copper	4	15	2.20	2.80	19.4×10^6
21	98.2	109	850	0.191	0.225	0.563	2.94	Molybdenum	8	60	4.35	8.63	54.8×10^6

* *Moyno booster pump used in tests 11, 12, and 18-20; gear booster pump used in other tests.*
** *Atmospheric-pressure discharge and 0% exit quality for all tests.*
‡ *Each slot measured 0.031 in. × 0.100 in., as shown in Figure 2.*
‡‡ *Of interior surface near exit of tube.*

tures and measured wall static pressure as a criterion. Boiling then occurs over an increasing tube length at higher heat fluxes. The increase of heat-transfer coefficient with heat flux in the nonboiling region of Figure 9 is probably caused by change of physical properties with temperature. For nonboiling, turbulent forced-convection in linear flow at a given weight flow rate,

$$h \propto [C_p^{1/3}\, k^{2/3}\, \rho^{0.8}/\mu^{0.467}] \qquad (14)$$

This factor, evaluated at the arithmetic mean film temperature for each of the three points at the left of Figure 9, undergoes a change of 36%, or about twice the variation of the calculated vortex coefficients. Figure 9 also shows the sharp increase of film temperature drop and wall temperature which begins about 20% below burnout.

Figure 10 is a cross plot of the originally calculated local coefficients vs. local heat flux. Coefficients at $L/D = 0$ are theoretically infinite, but values were calculated at this position by extrapolation of outer wall temperatures to $L_h = 0$ solely to show the general trend of h with (q/A). It is felt that h follows the general trend shown in Figures 9 and 10 even though the exact shape may be somewhat different.

E. Miscellaneous Observations. In all tests, the flow exhibited excellent stability up to the burnout point, and the system could be operated for considerable periods a few per cent below burnout.

No whistling or singing noises were noted as burnout was approached. This is a common phenomenon in straight-flow local boiling and may be absent in the vortex case because of the presence of a free liquid surface.

Pressure gauge P_3 of Figure 1 (at exit wall of test section) fluctuated moderately under adiabatic conditions but immediately stabilized when the switch was thrown and heat was generated in the test section. With increase of heat flux, there was a small increase of exit wall pressure.

Large amounts of air were seen dispersed in the exit water stream as it flowed through a transparent hose. This is to be expected, of course, when centrifuging and heating untreated water.

In vortex tests 15 and 20, all factors except test-section material are nearly identical and the burnout fluxes agree within 1%, indicating that at a heat flux level of 20×10^6 B.t.u./(hr.) (sq. ft.), the properties of copper and nickel compensate in a fashion advantageous to neither.

For vortex tests 13, 15, and 17, among which P_f varies by only ±3%, it may be seen that with nearly identical test sections burnout flux increases significantly with a*. With the 8-slot vortex generator of test 13, the burnout heat flux is 53% greater than with the 2-slot generator of test 17 at the same pumping power.

F. Possible Improvements. The burnout heat fluxes attained in this study could probably be increased by:

(1) Using d.-c. heating to avoid heat flux ripple and thermal cycling of the test section. This is easily the most promising improvement.

(2) Using distilled water. This change should not have much affect with vortex flow, since any gas or vapor in the system is transported to the center of the tube where it will do the least harm.

(3) Using one "floating" electrode to allow for test section thermal expansion.

(4) Using metals which generate lower thermal stresses and have higher strength at elevated temperatures. The Udimet "superalloys," niobium, molybdenum, and tungsten are superior in this respect.

continued

Table 3. Straight-flow Boiling Burnout Tests

Test No.	Velocity ft./sec.	Degree of subcooling at Exit, °F.	L_b, in.	(L_b/D_1)	(P_f/P_e)%‡	Exptl. $(q/A_1)_b$ B.t.u./(hr.)(sq. ft.)	$(q/A_1)_b$ from Eq. (8)
1	84.3	148	3.82	12.51	0.749	8.6×10^6	8.6×10^6
2	56.7	146	2.88	9.44	0.294	7.9×10^6	7.6×10^6
3	85.7	158	1.85	6.06	1.221	10.5×10^6	11.0×10^6
4	56.7	134	6.20	20.33	0.245	5.5×10^6	5.4×10^6
5	43.1	134	5.02	16.48	0.140	5.0×10^6	5.1×10^6
6	61.5	142	4.06	13.32	0.348	6.8×10^6	6.9×10^6
7	85.5	103	2.92	9.58	1.331	6.3×10^6	6.5×10^6

Notes—For all tests: $D_1 = 0.305$ *in.,* $D_2 = 0.375$ *in., tubes of "A" nickel, exit quality of 0%, atmospheric-pressure discharge.*

Static pressure in test section at inlet electrode, adiabatic conditions: 16 — 27 lb./sq. in. abs.

Temperature of inlet water: 5.2 — 8.2°C.

Temperature of exit water: 12.5 — 26.2°C.

Test-section inlet regions: see Figure 2.

‡ *Calculated for burnout condition, using total head loss for flow-work term* P_f.

Table 4. Maximum Range of Variables Covered

Variable	Vortex tests	Straight-flow tests
Burnout heat flux, B.t.u./(hr.) (sq. ft.)	7.3×10^6 to 54.8×10^6	5.0×10^6 to 10.5×10^6
Superficial axial velocity, ft./sec.	11.8 to 98.2	43.1 to 85.7
L/D ratio	2.0 to 12.0	6.1 to 20.3
Exit bulk subcooling, °F.	0 to 150	103 to 158
Area ratio a*, %	9.6 to 86.5	......
Internal wall roughness, Microinch rms	7 to 60	......

Table 5. Heat Flux Ranges

(q/A in B.t.u./(hr.) (sq. ft.))	
500 to 50,000	Process industry heat exchangers, 500 low for subcooling in condensers to 50,000 high for some vaporizers.
400,000	Peak flux for water in saturated pool boiling at one atmosphere.
216,000 to 1,150,000	Range for 12 thermal nuclear reactors of various types, maximum core heat flux (avg. = 1/3 to 1/6 of maximum).
2,000,000	Available parabolic reflector solar furnaces, maximum at focus.
5,000,000	Attained successfully in nozzle throats of operational liquid-propellant rockets.
6,000,000	Commercial "plasma jet" (water stabilized arc).
14,000,000	Maximum mentioned in literature for burnout with water in linear flow.‡
20,000,000	Maximum known to authors for water in linear flow.‡‡
55,000,000	Highest vortex-boiling burnout flux attained by authors.
1,160,000,000	Carbon sublimation cooling (air plasma heat input), millisecond duration.*

‡ *Glasstone, S.,* Principles of Nuclear Reactor Engineering, *p. 695, D. Van Nostrand, New York (1955).*

‡‡ *Private communication from D. E. Bloxsom, Jr., Marquardt Aircraft Company (February, 1958).*

* *Bloxsom, D. E., Jr.,* Heat Transfer and Fluid Mechanics Institute Reprints, *pp. 159-72, (1957).*

Boiling burnout

continued

It is felt that an extension of this study into higher ranges of L/D and of exit quality is desirable. A similar boiling burnout investigation, using tubes with tangential holes or slots along the entire length and tubes with internal twisted-strip swirl-producers, would perhaps be easier to analyze since natural vortex decay would not be an important factor.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Oak Ridge National Laboratory for permission to publish this material, to Joe Lones for his competent and enthusiastic assistance as project technician, and to Dolores Eden for her conscientious typing of the manuscript.

NOTATION

a^* = ratio of cross-sectional flow area of orifice or slots of vortex generator to cross-sectional flow area of test section

A_1 = inside heat-transfer surface, sq. ft.

C_p = specific heat at constant pressure, B.t.u./(lb.) (°F.)

D_1, D_2 = inside and outside diameters of test section, in.

E = modulus of elasticity in tension, lb./sq. in.; also voltage across test section

g_c = conversion factor in Newton's second law, ft-lb mass/(sec.)^2 (lb. force)

h = heat-transfer coefficient, B.t.u./(hr.) (sq. ft.) (°F.)

k = thermal conductivity, B.t.u./(hr.) (sq. ft.) (°F./ft.)

L_h = heated test-section length, in.

L_v = latent heat of vaporization, B.t.u./lb.

P = static pressure, lb./sq.in.

P_f = flow power dissipated across test section, hp.

P_q = heat-transfer rate at burnout point, hp.

ΔP = total pressure drop across test section, lb./sq. in.

q = heat-transfer rate, B.t.u./hr.

$(q/A_1)_b$ = burnout heat flux, B.t.u./(hr.) (sq. ft.)

R_1, R_2 = inside and outside wall radii, ft.

t_b = bulk water temperature, °F.

t_{sat} = saturation temperature, °F.

Δt_{sub} = degree of subcooling, °F. = $(t_{sat} - t_b)$

Δt_w = temperature drop across tube wall, °F.

V = axial velocity for straight flow, ft./sec.

V_{ax} = superficial axial velocity for vortex flow, ft./sec.

V_t = tangential velocity, ft./sec.

V_h = volume of heated test-section metal, cu. ft.

W = weight rate of flow, lb./hr.

x = steam quality at test-section exit, wt. %

α = linear coefficient of thermal expansion, °F.$^{-1}$

σ_{tti} = tangential thermal stress at inner wall surface, lb./sq. in.

Γ = circulation constant for a free vortex, ft./sec.

ρ = fluid density, lb./cu. ft.

ν = Poisson's ratio

μ = fluid viscosity

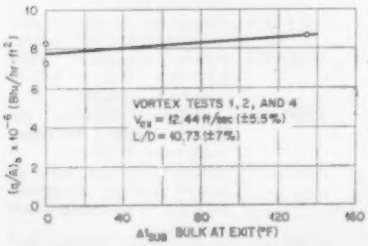

Figure 6. Illustration of the small dependence of burnout heat flux on degree of bulk subcooling.

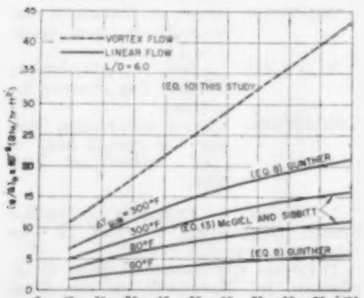

Figure 7. Calculated burnout heat fluxes for water in vortex and linear flow.

Appendix

I. Construction of Figure 8

For curve 1, Equation (8) was used to calculate P_q, and P_f was calculated from Equation (1), using the sum of velocity head and friction loss for ΔP. Friction loss was calculated from standard relations for linear flow without heat transfer. It is recognized that the ratio of pressure drop with heat transfer to the adiabatic pressure drop initially decreases with increase of heat flux, at equal liquid bulk temperature and flow rate. Upon inception of nucleate boiling, this ratio

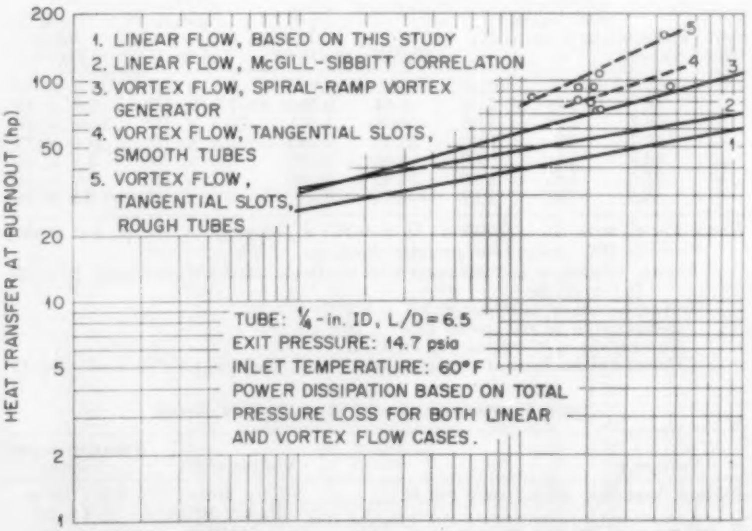

Figure 8. Comparison of heat transfer vs. power input for vortex and linear flow of water at local-boiling burnout.

. . . detailed supplementary material explains Figure 8, compares vortex and straight-flow burnout, calculates special coefficients.

reaches a minimum and then increases, and the final value at burnout may be above or below unity, but is usually not greatly different *(28)*. In the absence of a specific correlation, the adiabatic friction loss was used for this calculation at the burnout point.

For curve 2, P_q was calculated from the McGill-Sibbitt correlation, Equation (13), corrected from $L/D = 21$ to $L/D = 6.5$ by the rule that halving L/D increases $(q/A)_b$ by $\sim$ 15%. P_f was calculated as for curve 1.

For curves 1 and 2, a trial-and-error solution was necessary, since degree of exit subcooling, on which burnout flux and P_q depend, was not known in advance and had to be assumed.

For curve 3, P_q was calculated from Equation (11), and experimental pressure drop data for the spiral-ramp geometry were used for P_f. The vortex-flow over-all ΔP varied as the square of flow rate over a broad range and was extrapolated on this basis for some points of curve 3. The pressure drop in the vortex tube only was simply determined by subtracting the ΔP for the vortex generator plus transition cone (determined after the tube was cut off) from the ΔP for the entire assembly—vortex generator plus transition cone plus tube. The tube pressure drop was consistently only 2/10 of the total pressure drop; and if Figure 8 were based on tube ΔP only, the advantage for the vortex case would be much greater. Since the vortex generator is obviously an essential element of the system, however, all values of P_f for the vortex tests were based on over-all ΔP.

Curves 4 and 5 were plotted directly from the data for vortex tests 11 to 21. Experimental P_q values were corrected to the conditions of Figure 8 by a surface-area ratio and the L/D function of Equation (9). P_f was taken as the observed value; this is roughly true since ΔP for the various length test sections were generally a small portion of the total ΔP. For the tests with 8-slot vortex generators, however, tube ΔP was significant and curves 4 and 5 should be considered more qualitative than curves 1-3.

II. Comparison of vortex and straight-flow burnout on basis of true local conditions at exit wall

When the superficial axial velocities and "bulk degrees of subcooling" of Tables 1 and 2 are used in burnout prediction equations for straight flow, calculated values average about 1/4 to 1/5 the experimental vortex burnout fluxes.

The true fluid velocity at the exit wall, however, is greater than V_{az} and the actual value of Δt_{sub} at the wall is greater than the bulk Δt_{sub}. In order to determine whether use of the higher local values of V and Δt_{sub} could explain the large values of $(q/A)_b$ observed, measurements were made of exit-wall static pressure and of the ratio of air core diameter to tube diameter at the exit:

Vortex Test No.	P_3, lb./sq. in. gauge	$\sim(D_{air\ core}/D_1)$*
7	21	0.7
8	27	0.7
9	46	0.7

For any vortex, a radial force balance gives:

$$\frac{dP}{dR} = \frac{\rho V_t^2}{g_c R} \tag{15}$$

The tangential velocity distribution in a free vortex is:

$$V_t = \frac{\Gamma}{R} \tag{16}$$

Combination of Equations (15) and (16) and integration yields:

$$(P_{R2} - P_{R1}) = \frac{\rho}{2g_c}(V_{t1}^2 - V_{t2}^2) \tag{17}$$

Let sub $_1$ denote the air core-water interface and sub $_2$ the water-tube wall interface. From the observation that $D_1/D_2 \approx 0.7$, Equation (16) gives

$$\frac{V_{t1}}{V_{t2}} \approx 1.428 \tag{18}$$

Setting $P_{R1} = 1$ atm., Equations (17) and (18) may be solved simultaneously for the tangential velocities at the extreme boundary surfaces of the water annulus at the tube exit. Also, the true average axial velocity is approximately double the superficial value.

The exit vector velocity calculated from these tangential and axial com-

continued

**The value of 0.7 is approximate, but is in good agreement with data for swirl spray-nozzles as reported by Marshall (29).*

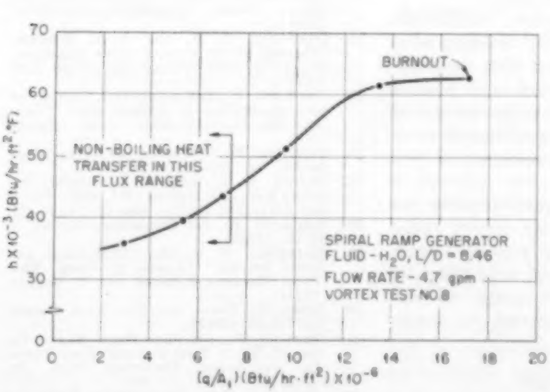

Figure 9. Variation of over-all heat-transfer coefficient with heat flux.

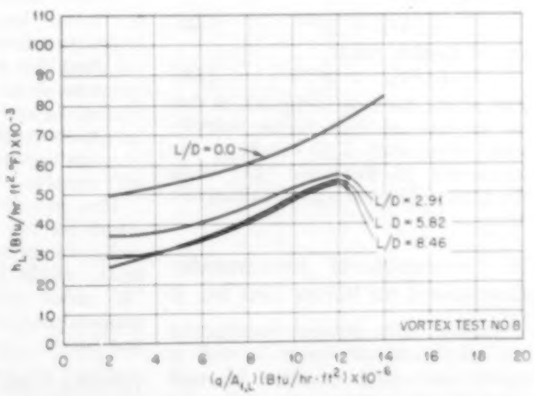

Figure 10. Local heat-transfer coefficients vs. local heat fluxes.

Boiling burnout

continued

ponents may be used along with the true exit subcooling, defined as $(t_{sat,\ wall,\ exit} - t_{b,\ exit})$, in Equation (8) to calculate burnout flux for equivalent straight flow, as shown right.

Test No.[a]	(L_h/D_1)	V_{exit}, ft./sec.[b]	$(\Delta t_{sub})^c$ °F.	Straight flow[d] $(q/A_1)_b$	Vortex flow[e] $(q/A_1)_b$	Ratio vortex/straight
7	12.00	86.1	66	3.93×10^6	13.10×10^6	3.33
8	8.46	96.6	109	7.53×10^6	15.15×10^6	2.01
9	4.73	112.4	169	14.10×10^6	18.60×10^6	1.32

[a] Total flow rate and tube diameter nearly identical for all three tests.

[b] Vector velocity from true average axial component and arithmetic average of V_{t1} and V_{t2}.

[c] Local value at exit wall.

[d] From Equation (8) for straight flow, B.t.u./(hr.)(sq.ft.).

[e] Value at test-section exit, B.t.u./(hr.)(sq.ft.).

It is apparent that a mechanism is operative which is not accounted for by the usual parameters of velocity and subcooling. It is believed that this mechanism is one of radial vapor transport by the centrifugal acceleration.

In addition, vortex burnout fluxes vary much more nearly in proportion to the change of vector velocity than to the change of subcooling. The burnout flux predicted for straight flow is nearly as large as the vortex value of low L/D because the degree of subcooling is large, and dependence is on the first power at Δt_{sub}. As L/D increases, Δt_{sub} decreases rapidly and so does $(q/A)_b$ for straight flow.

If the rotation rate and magnitude of centrifugal acceleration at the tube exit are calculated from:

$$\text{RPM} = \frac{V_t}{\pi D_1/60} \tag{19}$$

and

$$\text{Gees} = \frac{V_t^2}{32.2\, R_1} \tag{20}$$

the results are:

Test No.	Avg. exit RPM	"Gees" at exit wall
7	56,500	8,390
8	66,600	11,780
9	82,400	18,000

If the increase in $(q/A)_b$ from test 7 to test 9 is attributed solely to the increase in g, then the data indicate that:

$$(q/A)_b \propto g^{0.43-0.48} \tag{21}$$

which is in fair agreement with the proposed burnout prediction equations of Zuber *(30)*:

$$(q/A)_b \propto g^{0.25} \tag{22}$$

and of Griffith *(31)*:

$$(q/A)_b \propto g^{0.333} \tag{23}$$

Part of the increase in $(q/A)_b$ is due to increase of exit vector velocity with decreasing L/D, making the agreement of Equation (21) with Equations (22) and (23) qualitatively better.

III. Calculation of Heat-transfer Coefficients for Vortex Test No. 8

To take into account variation of wall thickness with length as well as radial and axial variation of wall thermal conductivity, the following procedure was used:

(a) The over-all measured heat flux was assumed to occur as a local value at the length corresponding to the mean cross-sectional electrical area of the tube. Heat fluxes at other lengths were then calculated from ratios of electrical area.

(b) Power density (q/V_h) was obtained by dividing local heat flux by local wall thickness. (q/V_h) was also plotted vs. length.

(c) Water temperature as a function of length was calculated by dividing the test section into three equal linear zones and successively applying to each zone the relation:

$$t_{b\ out} = t_{b\ in} + \frac{(q/A_1)_{mean}\, A_1}{WC_p}$$

(d) Equation (6) was then used for a trial-and-error solution of Δt_w. A mean wall thermal conductivity was assumed for each axial position, Δt_w calculated, and k at the arithmetic mean of measured outside wall temperature and calculated inside wall temperature compared with the assumed k. This process was repeated until Δk was less than 1%. It was necessary to use a desk calculator to compute the geometrical factor of Equation (6) because of its numerical sensitivity. Thermal conductivity values of "A" nickel were taken from *(32)*.

(e) Local heat-transfer coefficients were calculated by dividing local heat flux by local film temperature drop. Local h was plotted vs. L_h and graphically integrated to obtain the over-all length average inside film coefficient of heat transfer.

This procedure approximately accounts for all variables except radial and axial variation of electrical resistivity, which changes negligibly for "A" nickel over the range of wall temperatures encountered in vortex test No. 8.

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Nucleate boiling —a correlation

A bold approach to the correlation of existing data for determining the film coefficient of nucleate boiling, in contrast to the usual methodical approach, has been used successfully.

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HEAT TRANSFER TEXTBOOKS do not contain a comprehensive yet simple expression for the determination of the film coefficient for nucleate boiling. A possible explanation is that the present methods of correlation are not fundamentally correct. There is no doubt that nucleate boiling coefficients are proportional to power functions at ΔT, flux (B.t.u./(hr.) (sq.ft.), pressure and other variables. But the mechanism of the boiling process is not apparent in any of these correlations. For sensible heat transfer or for condensing, the published expressions are given in terms of equalities between dimensionless groups. There is an obvious relationship between the terms in the group and the mechanism of heat transfer. If a similar type of correlation could be developed for nucleate boiling, the problems of the design or rating engineer would be simplified. At present, each engineer must resort to his own interpretations of present correlations and, as a result, the user or purchaser of reboilers or vaporizers receives several discrete designs for a given duty.

Material supplementary to this article has been deposited as Document number 5708 with A.D.I. Auxiliary Publications Project, Photoduplication Service, Library of Congress, Washington 25, D. C. Photoprints or microfilm obtainable by remitting $1.25.

The purpose of this paper is to present an expression for nucleate boiling which resembles those for sensible heat transfer and condensing and which is based on a new and satisfactory correlation of existing data. No new experimental data are included in this correlation. It is hoped that this expression will find favor among novice rating engineers. Further, it is hoped that future experimenters may attempt to make use of this expression in both the design of their experiments and the correlation of their results

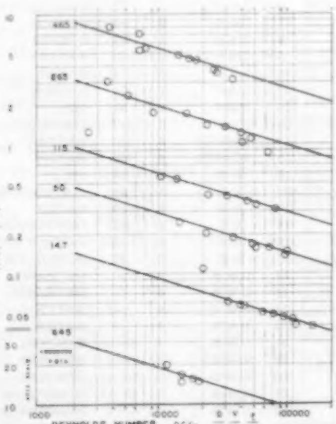

Figure 1. Data of Cichelli and Bonilla—Boiling benzene. Plot of Reynolds number vs. Colburn j factor.

Argument

In contrast to the usual methodical approach used in correlating data, the method used here is bold. An equality of three familiar dimensionless groups is written along with an additional new dimensionless group to take care of pressure and surface tension. This expression follows:

$$\left(\frac{h}{CG}\right)^{a}\left(\frac{C\mu}{k}\right)^{b}\left(\frac{\rho_L\sigma}{P^2}\right)^{e} = \frac{\Phi}{(DG/\mu)^{d}} \quad (1)$$

The left-hand side of this expression will be called the Colburn *j*-function for nucleate boiling and the function in the denominator of the right-hand side is the familiar Reynolds number. The objective is to find the exponents and to define the mass velocity term.

Cichelli and Bonilla (*1*) published a considerable amount of data on boiling of water and organic compounds at pressures above 1 atm. Cryder and Finalborgo (*2*) published data on water and organics at pressures below one atmosphere. These data are used to establish the exponent on the "pressure number" and, incidentally, to corroborate the exponents chosen for the other dimensionless groups. To simplify the presentation of this correlation, only the data for benzene from Cichelli and Bonilla and the data for methanol from Cryder and Finalborgo are used. To prove that the above procedure does not represent a fortuitous selection, additional data from these experimenters will be plotted on the final graph along with data published by several other authors.

The exponent on the Stanton number (h/cG) is usually unity. It is so assumed in this derivation.

The exponent on the Prandtl number $(c\mu/k)$ for liquid heating is usually 0.6. Since boiling is definitely a heating process, it is assumed that it is permissible to use this value for the exponent here.

Before a value can be assigned for the exponent on the Reynolds number, it is necessary to define mass velocity. This step is one of the major contributions made in this development. The vapor is generated from various points over the heated surface. If V=lb./hr. vapor produced and A is the surface area, the units of the quotient V/A are lb./(hr.) (sq.ft.), a mass velocity. However, this is not the mass velocity which affects the

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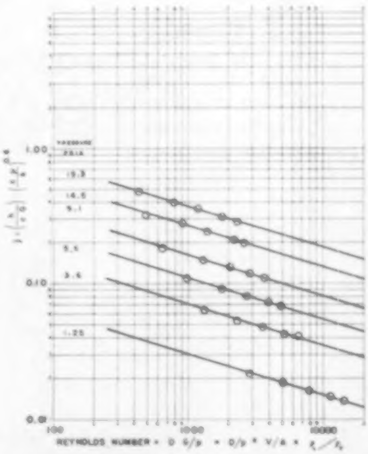

Figure 2. Data of Cryder and Finalborgo—Boiling methanol. Plot of Reynolds number vs. Colburn j factor.

Nucleate boiling

continued

liquid film. If the quotient V/A is divided by vapor density, the quantity is the volume of vapor per hour per square foot leaving the surface. This volume of vapor is replaced by an equal volume of liquid so if the new quotient is multiplied by the density of the liquid, the net result is the mass velocity of the liquid returning to the surface. The expression for mass velocity (normal to the tube or surface) is thus:

$$G = \frac{V}{A}\frac{\rho_L}{\rho_V} \qquad (2)$$

Data of Cichelli and Bonilla for benzene at six pressures are plotted on Figure 1 using the above expression for mass velocity and using, for D, the diameter of the disk. A value of 7-7/8 in. obtained (*1*, p. 756) was used but the effective diameter is actually 4 in. This error does not influence the slope of the lines in Figure 1. In Figure 2 the data of Cryder and Finalborgo for methanol at six pressures are plotted. In both instances, the slope of the lines is clearly —0.3. This then is the exponent on the Reynolds number.

Before proceeding with the cross-plots of the data of Figures 1 and 2, it might be of interest to show how the value of this exponent can be obtained algebraically. The heat transfer coefficient is often shown to be a function of the 2.4 power of ΔT. By substituting this in a heat balance relationship between heat transferred and heat load it may be shown that h varies directly with approximately the 0.7 power of mass velocity. The exponent on G in Equation (1) is 0.7 if $a = 1$ and $d = 0.3$ [a and d are exponents indicated in Equation (1)]

$$hA\Delta T = V\lambda \qquad (a)$$

$$h = a\Delta T^{2.4} \qquad (b)$$

From (b)

$$\Delta T = (h/a)^{0.416} \qquad (c)$$

Substitute (c) in (a)

$$hA(h/a)^{0.416} = V\lambda \qquad (d)$$

$$h^{1.416} = \left(\frac{V}{A}\right) \lambda\, a^{0.416} \qquad (e)$$

$$h = (V/A)^{0.706}\, \lambda^{0.706}\, a^{0.416} \qquad (f)$$

Thus h is proportional to the 0.7 power of mass velocity.

Cross-plots of the data in Figures 1 and 2 may be used to obtain the exponent on the pressure number. The range of values for the functions is so great that it was considered desirable to superimpose the data. This was done by selecting a different set of coordinates for each set of data. The line drawn through the points on Figure 3 has an apparent slope of 0.425. This is the value of exponent c in Equation (1). The only excuse for three significant figures for this exponent is that all the other exponents were assumed to be expressible to one significant figure. Any errors in this assumption will accumulate in the final cross-plot and it is necessary to determine this slope with a reasonable degree of accuracy.

The final correlation thus becomes:

$$\left(\frac{h}{CG}\right)\left(\frac{C\mu}{k}\right)^{0.6}\left(\frac{\rho_L\sigma}{P^2}\right)^{0.425} = \frac{\Phi}{(DG/\mu)^{0.3}} \qquad (3)$$

in which

$$G = \frac{V}{A}\frac{\rho_L}{\rho_v} \qquad (2)$$

The proportionality constant will be obtained from the final plot with data from several investigators.

Substantiation

In the development up to this point, the data of only two investigators and of only two fluids have been used. Additional data from various investigations on nucleate boiling have been plotted on Figure 4. These data are identified by numbers on the chart. Only one or two points from a series of data of a single investigator are plotted, with the range from a Reynolds number of 120 to 500,000 and from a j-factor of 2.5×10^{-4} to 1.9×10^{-5}.

Plotting data for boiling from disks necessitates the selecting of a diameter term which is not the diameter of the disk. However, the diameter term selected is a constant for any one disk diameter, it is thus thought

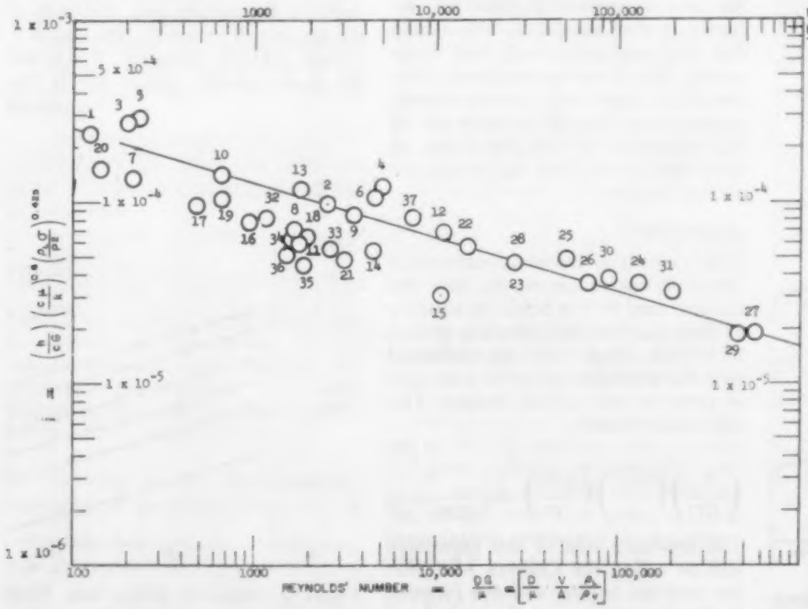

Figure 4. Correlation of nucleate boiling data. Plot of j vs. Reynolds number.

PLOT NO.	EXP.	LIT. NO.	RUN	FLUID
1	C & G	3	78	METHANOL
2	C & G	3	96	METHANOL
3	C & G	3	12	WATER
4	C & G	3	13	WATER
5	C & G	3	65	CCl_4
6	C & G	3	77	CCl_4
7	C & G	3	98	N-BUOH
8	C & G	3	109	N-BUOH
9	C & F	2	12	WATER
10	C & F	2	15	WATER
11	C & F	2	101	N-BUOH
12	C & F	2	92	CCl_4
13	C & F	2	217	24% NaCl
14	BOARTS	4	150	WATER
15	BOARTS	4	159	WATER
16	I & B	5	IA	CCl_4
17	I & B	5	IA	40% SUCROSE
18	I & B	5	IA	WATER
19	I & B	5	IIC	ISOPROPANOL
20	I & B	5	IB	ISOPROPANOL
21	I & B	5	IC	WATER–TRITON
22	D & V	6	—	METHANOL
23	D & V	6	—	METHANOL
24	D & V	6	—	WATER
25	D & V	6	—	WATER
26	C & B	1	56–17	BENZENE
27	C & B	1	53–1	BENZENE
28	C & B	1	56–11	BENZENE
29	C & B	1	42–23	N-HEPTANE
30	C & B	1	42–6	N-HEPTANE
31	C & B	1	69–1	ETHANOL
32	M & K	7	—	F-12
33	M & K	7	—	MeCl
34	M & K	7	—	SO_2
35	M & K	7	—	BUTANE
36	M & K	7	—	PROPANE
37	P & W	8	—	METHANOL

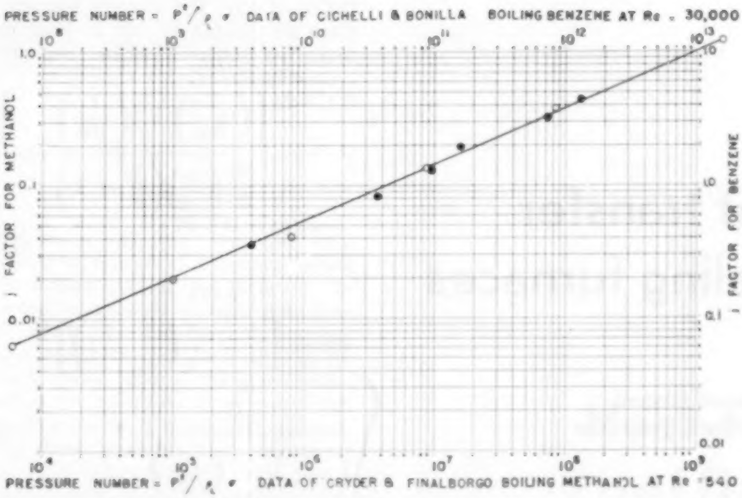

Figure 3. Cross plot of j factor vs. pressure number.

that this selection of a length factor is justified.

The line which appears on Figure 4 is not necessarily the best line through all the points that were plotted but it is considered to be a conservative line from the standpoint of design. The Gilliland data which, in some cases, fall above the line are considered to be the best from the standpoint of true nucleate boiling. These investigators appear to have preheated the liquid feed to the boiling point before it was introduced into the experimental boiler. When reflux condensers were used, it seems probable that the condensate returning to the boiler was partially subcooled and it would be expected that this would have some effect upon the film coefficient.

It is well known that the material of construction of the boiling surface influences heat transfer. The line shown on Figure 4 is representative of the heat transfer obtained from copper or steel surfaces. The data for experiments in which stainless or chromium surfaces were used indicate that the heat transfer coefficients are about 43% lower than those for copper or steel surfaces. In plotting the data of Cichelli and Bonilla, the length term in the Reynolds number was deliberately chosen so that most of the data fell on the final line; although actually, because the surface was chromeplated, the data should fall below the line drawn through data for copper surfaces.

Although some data for nucleate boiling from wires have been plotted in accordance with this correlation, the agreement with the plotted curve is not good. There are two reasons for this: first, the wires are usually of platinum or other metals with an exceptionally bright surface; second, the bubble size at the time it leaves the surface of a wire is possibly equal to, or greater than, the diameter of the wire and therefore the full effect of the impingement of returning liquid is not realized. Polished surfaces appear to have coefficients about 60% lower than those for commercial copper or steel surfaces.

Heat transfer specialists may be reluctant to accept this correlation because they are accustomed to thinking in terms of flux and maximum temperature difference for nucleate boiling. Although this condition of maximum flux is rarely encountered in ordinary industrial reboilers, a considerable amount of published data indicates that this maximum condition occurs when the superficial vapor velocity lies in the range of from 0.6 to 1.0 ft./sec. It is fairly well established that bubbles in a quiescent pool of liquid travel vertically at velocities within the range indicated. If an attempt is made to produce bubbles at a rate greater than that which would result in a superficial velocity of approximately 1.0 ft./sec., the bubbles will remain in the vicinity of the tube wall thus blanketing it with a gas film which will naturally cause a reduction in heat transfer. In commercial tube bundles this condition sometimes exists when tube spacing is close and when insufficient disengaging space between the bundle and the kettle exists. If natural circulation can take place, it is possible to maintain boiling at higher vapor velocities.

For design purposes, the following equation is recommended for the case in which nucleate boiling is the mechanism of heat transfer.

$$\left(\frac{h}{CG}\right)\left(\frac{C\mu}{k}\right)^{0.6}\left(\frac{\rho_L\sigma}{P^2}\right)^{0.425} = \frac{0.001}{(DG/\mu)^{0.3}}$$

in which $G = \dfrac{V}{A}\dfrac{\rho_L}{\rho_V}$

This equation has the form of usual equations for sensible heat transfer. It has been used successfully in the design of hundreds of vaporizers and reboilers.

NOTATION

a = a proportionality constant
A = surface area, sq.ft.
c = specific heat of liquid, B.t.u./(lb.) (°F.)
D = diameter of tube, ft.
G = mass velocity of liquid, (lb.)/(hr.) (sq. ft.) [defined Equation (2)]
h = film coefficient of heat transfer, B.t.u./(hr.) (sq. ft.) (°F.)
j = Colburn j-factor, dimensionless [defined by left-hand side of Equation (1)]
k = thermal conductivity of liquid, B.t.u./(hr.) (ft.) (°F.)
P = pressure at which fluid is boiling, lb./sq. ft.
ΔT = Temperature difference between boiling fluid and wall, °F.
V = vapor rate, lb./hr.
λ = latent heat of vaporization, B.t.u./lb.
μ = viscosity of liquid, lb./(hr.) (ft.)
ρ_L = density of liquid, lb./cu.ft.
ρ_V = density of vapor, lb./cu.ft.
σ = surface tension of liquid, lb./ft.
Φ = a proportionality constant
1×10^{-3} for copper and steel surfaces
5.9×10^{-4} for stainless steel or chromium-nickel alloys
4.0×10^{-4} for polished surfaces

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Radiant heat transfer in sheet annealing furnaces

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Present day trends in the manufacture of metal sheets call for high-speed continuous annealing lines. In order to get the necessarily high rates of heat transfer, radiation is resorted to. As some of these continuous annealing lines run as fast as 1,000 ft./min., large differences in temperature and considerable amounts of exposed area are essential.

Most furnaces now in use operate without heat recovery. In order to design such annealing furnaces, some integrated equations or curves relating radiant heat transfer to the temperature changes of the sheet strip passing through the furnaces are necessary. Such equations or curves are also useful in determining the time-temperature history of the strip in the annealing furnaces for metallurgical purposes. It is probable that residence times are too short to permit any grain growth in the strip, but the strains due to work hardening are doubtless relieved. These equations are presented in the following section:

This article is a condensation of the paper given at the 1958 A.I.-Ch.E.—A.S.M.E. Second Annual Heat Transfer Conference held in Chicago, Ill.

The differential heat balance and radiant rate equations are written in the usual way. The absolute temperatures are divided by 100 in order to make the Stefan-Boltzmann constant a convenient size.

$$\frac{0.173\, dA\left[\left(\frac{T}{100}\right)^4 - \left(\frac{t}{100}\right)^4\right]}{\frac{1}{E}+\frac{A}{a}\left(\frac{1}{e}-1\right)} = wc\,dt = WC\,dT \qquad (1)$$

$$\frac{0.173\ A}{100\,wc\left[\frac{1}{E}+\frac{A}{a}\left(\frac{1}{e}-1\right)\right]} = \int \frac{\frac{dt}{100}}{\left(\frac{T}{100}\right)^4-\left(\frac{t}{100}\right)^4} = \mathrm{I} \qquad (2)$$

In these equations capital letters refer to the hot body radiator, and the lower case letters refer to the cold body absorber.

$$\text{Let:}\quad u=\frac{t}{100}\ \text{and}\ v=\frac{T}{100} \qquad (3)$$

When the hot body radiator (T) is at a constant temperature, integration leads to:

$$g^3\mathrm{I} = \tfrac{1}{2}\left[\tan^{-1}\left(\frac{u}{v}\right) + \tanh^{-1}\left(\frac{u}{v}\right)\right] \qquad (4)$$

$$\text{where:}\quad g = \frac{T_1 - Rt_2}{100} \qquad (5)$$

$$\text{and}\quad R = \frac{wc}{WC} \qquad (6)$$

In this case with T = constant, R = 0

If the countercurrent flow case is considered, integration of Equation (2) leads to:

$$g^3 I = \tfrac{1}{4}(R^2+1)\ln\frac{1+\left(\frac{u}{v}\right)}{1-\left(\frac{u}{v}\right)} - \tfrac{1}{2} R \ln \frac{1+\left(\frac{u}{v}\right)^2}{1-\left(\frac{u}{v}\right)^2} - \tfrac{1}{2}(R^2-1)\tan^{-1}\frac{R+\left(\frac{u}{v}\right)}{1-R\left(\frac{u}{v}\right)} \qquad (7)$$

In an annealing furnace the same strip moving at the same velocity

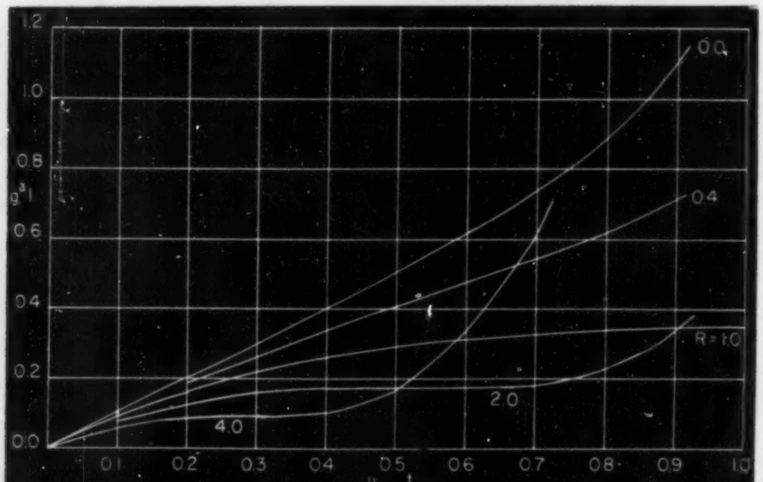

Figure 1. On this graph curves 0.0, 0.4, and R=10 are plots of countercurrent flow, and curves 4.0 and 2.0 are plots of parallel flow.

and having substantially constant heat capacity constitutes both hot body and cold body so that R = 1 and Equation (7) reduces to:

$$g^3I = \tfrac{1}{2} \ln \frac{\left(1+\frac{u}{v}\right)^2}{1+\left(\frac{u}{v}\right)^2} \qquad (8)$$

Equations (4), (7), and (8) constitute a family of functions which have been plotted on Figure 1. In order to make g^3I = zero at $u/v = 0$, as it obviously should, integration constants must be evaluated for each curve. This is done by evaluating the equations at $u/v = 0$ for each value of R taken and subtracting these constants from the results at other values of u/v. Each time a radiant heat exchanger problem is to be solved the temperature conditions at each end of the furnace section must be evaluated. Since:

$$\frac{u}{v} = \frac{t}{T} \qquad (9)$$

it is necessary to establish a heat balance and divide the absolute temperature of the cold body by the absolute temperature of the hot body at each end. Values of g^3I are obtained from the appropriate curve and subtracted one from the other. These values correspond to the limits of the integration and their difference is set equal to the expression: (10)

$$\Delta(g^3I) = \frac{0.173Ag^3}{100wc\left[\frac{1}{E} + \frac{A}{a}\left(\frac{1}{e} - 1\right)\right]}$$

Equation (10) will give the necessary area of exposure of the hot body A providing the ratio of areas A/a and the emissivities E and e are known.

NOTATION

Subscript 1 refers to the inlet temperature, and subscript 2 refers to the outlet temperature.

a, A = exposed area, sq. ft.
c, C = heat capacity, Btu/(lb) (°F.)
d = differential
e, E = emissivity of the surface
g = parameter defined by Equations (5) and (10)—°R
I = integral function defined by Equation (2)
ln = natural logarithm
R = wc/WC
t, T = temperature, °R
$\tan^{-1}$ = trigonometric arc tangent
$\tanh^{-1}$ = hyperbolic arc tangent
u = t/100, °R
v = T/100, °R
w, W = mass rate of strip flow, lb./hr.

Heat transfer coefficients observed in small sodium exchangers

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This article is a condensation of the paper given at the 1958 A.I.Ch.E.—A.S.M.E. Second Annual Heat Transfer Conference held in Chicago, Ill.

Liquid metals continue to be of great interest as nuclear reactor coolants. One fundamental quantity required for design of such coolant systems is the heat transfer coefficient. Despite much interest and several theoretical and experimental investigations, the prediction of liquid metal heat transfer coefficients is still not satisfactory. The experimental results are not in agreement with theory. The results to be reported herein lend support to an empirical procedure that may be useful to designers with problems that cannot wait for the full understanding yet to come. In particular, observations were made on a "figure-of-eight" system containing flowing sodium.

Dimensions for exchangers are given in Table 1.

On exchanger B, temperatures were measured in thermocouple wells extending radially to the center line of the pipe carrying the sodium stream to or from the exchanger. The connecting piping was ⅜ in. schedule 40. The well at the tube inlet was 1⅜ in. from the tube and was ⅜ in. from the tube outlet. Wells at the annulus inlet and outlet were 1¼ in. from the exchanger center line in the ⅜ in. pipe perpendicular to the annulus. The hotter stream was in the inner tube. The double-tube assembly had a free-sliding fit at the hotter end to allow for differential expansion. The water leak rate through this sliding joint was 0.00127 gal./min. at 40 in. water pressure at 20°C. The operating pressure differential was less than 10 in. The exchanger was insulated with 1 in. Kaowool and 2 in. Thermobestos on the outside.

Observations and results

The over-all coefficients observed were calculated in the following manner: from flow rates and temperatures at both ends of the exchangers

continued

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Sodium exchangers

continued

the heat transferred to or from the stream in the tube was calculated. These same temperatures gave a log mean temperature driving force. The heat transferred, divided by this log mean temperature, and an inside or outside surface area gave an over-all coefficient based on the corresponding area. The over-all coefficient observed was based on the inside tube wall area for exchanger A. The over-all coefficient observed was based on the outside surface of the tube (inside surface of the annulus) for exchanger B. These choices were made to correspond with the location of maximum thermal resistance.

In experimental work with tube and annulus exchangers, earlier researchers separated the two film heat transfer coefficients by assuming their ratio to be in accord with the ratio of predicted values. The coefficients reported here are separated in a similar manner. The assumption is made that the tube and annulus coefficients are in the ratio of equations $Nu = 4.5 + 0.014\ (Pe)^{0.8}$ . . . *(1)* . . . and $Nu = 1.32\ (Pe)^{0.31}$ . . . *(2)* . . . even though they may not be exactly represented by these equations. From the observed over-all resistance, the wall resistance is subtracted. The remainder is divided into two parts, tube and annulus, in accord with ratio predicted by Equations (2) and (6) for the observed Peclet numbers. Conventional equations summing individual film resistances are used, with the recommended equation for each film substituted herein:

$$\frac{1}{U_iD_i} = \frac{1}{h_iD_i} + \frac{l_w}{k_wD_w} + \frac{1}{h_oD_o}$$

$$R = \frac{h_i}{h_o} = \frac{\dfrac{k}{D_i}\ (4.5+0.014Pe^{0.8})}{\dfrac{k}{D_e}\ (1.32Pe^{0.31})}$$

$$\frac{1}{U_i} = \frac{1}{h_i} + \frac{l_wD_i}{k_wD_w} + \frac{RD_i}{h_iD_o}$$

$$h_i = \frac{\left(1+R\ \dfrac{D_i}{D_o}\right)}{\dfrac{1}{U_i} - \dfrac{l_wD_i}{k_wD_w}}$$

Table 1

	Exchanger A	Exchanger B
Inner		
tube I.D.	0.930 in.	0.125 in.
O.D.	1.00 in.	0.165 in.
Outer		
tube I.D.	1.31 in.	0.364 in.
O.D.	1.50 in.	0.540 in.
Length	111 in.	44 in.
D_o/D_i	1.31	2.21
L/D_e	358	221

The observations and calculations are given in Table 2. It is worthy of note that in exchanger A the wall thermal resistance was 25% of the total and in exchanger B it was 45% of the total. The observed over-all coefficient should be compared to the predicted over-all coefficient. This is the only really reliable information obtained. The individual tube and annulus coefficients are calculated in a manner subject to criticism. The correct separation of tube and annulus data could be done only with measurements of the wall temperature between them.

The length of run numbers shows the great stability of the observed coefficients over long times.

Conclusion

For calculation of over-all heat transfer coefficients for tube and annulus exchangers, the following equations are recommended:

For tube: $Nu = 4.5 + 0.014\ (Pe)^{0.8}$

$60 < Pe < 450$

For annulus: $Nu = 1.32(Pe)^{0.31}$

$30 < Pe < 110$

ACKNOWLEDGMENT

This work was done on a subcontract from the Pratt and Whitney Aircraft Division.

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Table 2

	Exchanger A					Exchanger B					
Sodium flow, lb./hr.	852	1,060	938	620	442	388	356	330	293	421	187
Tube velocity, ft./sec.	1.03	1.28	1.15	0.75	0.53	26.9	24.0	22.9	20.3	29.2	13.0
Tube Re number	29,800	37,100	33,200	21,700	15,400	102,000	91,000	87,000	77,000	111,000	50,000
Tube Pe number	119	148	132	87	61	410	378	350	310	446	194
Tube coefficient by *(1)* B.t.u./(hr.) (sq. ft.) (°F.)	1,890	2,060	1,970	1,660	1,440	22,700	22,100	21,500	20,500	23,700	17,000
Tube coefficient by eq. 1 B.t.u./(hr.) (sq. ft.) (°F.)	2,270	2,340	2,320	2,220	2,180	20,600	20,200	19,900	19,400	21,000	18,000
Tube coefficient by (3) B.t.u./(hr.) (sq. ft.) (°F.)	3,630	3,720	3,670	3,520	3,400	33,400	32,600	32,100	31,500	34,100	28,600
Tube coefficient calculated B.t.u./(hr.) (sq. ft.) (°F.)	2,720	2,810	2,360	2,880	1,720	20,600	21,100	22,100	20,400	20,400	18,300
Annulus velocity ft./sec.	1.23	1.53	1.37	0.90	0.64	4.00	3.57	3.41	3.02	4.35	1.94
Annulus Re number	12,000	15,000	13,400	8,700	6,220	24,000	21,600	20,600	18,200	26,200	11,700
Annulus Pe Number	48	60	54	35	25	98	90	81	74	105	47
Annulus coefficient by (4) B.t.u./(hr.) (sq. ft.) (°F.)	8,350	8,450	8,420	7,440	7,350	15,800	15,700	15,500	15,300	15,900	14,900
Annulus coefficient by eq. 2 B.t.u./(hr.) (sq. ft.) (°F.)	5,850	6,290	6,080	4,810	4,330	11,400	11,000	10,700	10,400	11,700	9,100
Annulus coefficient calculated B.t.u/(hr.) (sq. ft.) (°F.)	7,020	7,550	6,170	6,240	3,410	11,500	11,500	11,800	10,900	11,500	9,250
Over-all coefficient by eq. 1 and eq. 2 B.t.u./(hr.)(sq. ft.)(°F.)	1,240	1,300	1,270	1,150	1,110	3,420	3,400	3,360	3,290	3,500	3,100
Over-all cofficient observed B.t.u/(hr.) (sq. ft.) (°F.)	1,420	1,460	1,280	1,440	943	3,470	3,480	3,550	3,400	3,460	3,140
Length of run, hrs.	12	46	376	814	1,690	7	22	44	145	1	6

Performance of a falling film evaporator concentrating milk

Jesse F. Keville, Carrier Corp., Syracuse, N. Y.

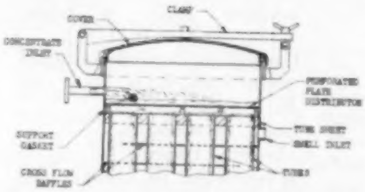

Figure 1. Functional view of inlet head.

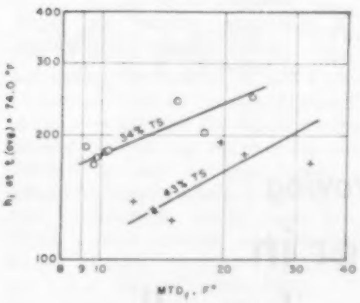

Figure 2. Boiling film coefficients vs. temperature difference.

This paper will discuss the heat transfer studies which were conducted using a falling film evaporator to concentrate milk. Data and correlations are presented which could be useful in likewise predicting the performof other fluids. It is believed that essentially all the necessary heat transfer information has been obtained for the design of falling film evaporators to concentrate whole milk, skim milk, whey, and sweetened condensed milk.

The low temperature tests were devoted to concentrating skim and whole milk under vacua corresponding to boiling points between 50 and 100°F. The high temperature tests were devoted to concentrating whole milk and milk products at vacua corresponding to boiling temperatures between 110 and 150°F. A centrifugal pump circulated the liquid being concentrated from the bottom of the separation chamber to the top or inlet head of the concentrator. The inlet head design is shown in Figure 1. The liquid was then distributed in such a way that it flowed down the inside wall of vertical, 3-in. O.D., stainless steel tubes in a thin film. Warm water on the outside of the tubes caused the falling liquid film to boil. The tube bundle consisted of ten tubes, 10 ft., long, but in some tests a number of the tubes were plugged to give higher heat flux per square foot of surface since total evaporation rate was limited by the size of the condenser. The warm water on the shell side of the concentrator was heated by injecting steam.

Figure 2 shows curves obtained by plotting some values of the boiling film coefficient vs. the calculated mean temperature difference across the boiling film. The curves represent different concentrations of total solids in the milk corresponding to volume reductions of 3:1 (34%TS) and 4:1 (43%TS). Figure 2 illustrates two important aspects:

This article is a condensation of the paper given at the 1958 A.I.Ch.E.–A.S.M.E. Second Annual Heat Transfer Conference held in Chicago, Ill.

A. Increasing the temperature difference for a given concentration and temperature level increases the boiling film coefficient.

B. Increasing the solids concentration of the milk decreases the boiling film coefficient.

C. The effect of the circulation rate

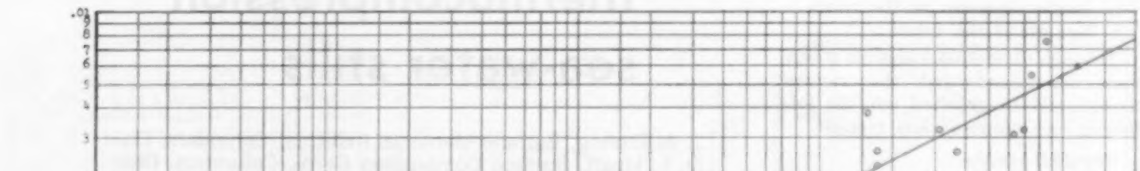

Figure 3. Data correlation.

Evaporator

continued

of the concentrate was investigated. A sanitary positive displacement pump was substituted for the centrifugal pump in two runs. The type of pump appeared to have no effect on the homogenization of the milk or on the performance of the evaporator. Both pumps were carefully calibrated by plugging all the tubes and timing the filling up of the inlet head using water. Corresponding volumetric efficiencies, for the concentrated milk in the actual runs were estimated based on the viscosity of the liquid. The tests confirmed the calculations that a minimum of approximately 3 gal./min./tube was required to wet the surfaces of the tubes completely. At circulation rates above 3 gal./min./tube, no evidence was found to indicate that variation in the circulation rate had a significant effect on performance.

A plan of calculation was undertaken in order to determine if an empirical equation could be fitted to the majority of the data. As a result of a review of the literature and consideration of the properties and conditions affecting the falling film, it was decided that the correlation should include the following terms:

a. Specific gravity of the concentrate
b. Viscosity of the concentrate
c. Velocity of the vapor
d. Thermoconductivity of the concentrate
e. Specific heat of the concentrate
f. Absolute pressure
g. Surface tension of the concentrate
h. Inside diameter of the tubes
i. Length of the tubes

Through dimensional analysis it was then determined that the various terms could be grouped into the following four dimensionless groups:

Reynolds number:

$$\frac{Dv_v\rho}{\mu} \text{ or } N_{Re}$$

Nusselt number:

$$\frac{h_iD}{k} \text{ or } N_{Nu}$$

Prandtl number:

$$\frac{c\mu}{k} \text{ or } N_{Pr}$$

Pressure, length, surface tension relation: $\frac{PL}{\sigma}$

The data were correlated by the following equations and are represented by the curve in Figure 3:

$$N_{Nu} = 5.40 \times 10^{-6} (N_{Re})^{0.5} (N_{Pr})^{0.3} \left(\frac{PL}{\sigma}\right)^{0.9}$$

where $N_{Re} > 7{,}000$

$$N_{Nu} = 1.98 \times 10^{-5} (N_{Re})^{0.35} (N_{Pr})^{0.3} \left(\frac{PL}{\sigma}\right)^{0.9}$$

where $N_{Re} < 7{,}000$

Average deviation of the data points from the curve is 13 per cent.

Conclusions

A successful graphical and equation-type correlation of the boiling heat transfer coefficient as related to fluid properties and equipment geometry has been obtained for the evaporation of milk in a falling film evaporator. It is believed that the correlation will apply to whole milk, either homogenized or nonhomogenized, provided the ratio of solids non-fat to butter fat is in the range of 2.3 to 2.6.

Work on this paper was done at Syracuse Univ.

Notation

N_{Nu} = Nusselt number = $\frac{h_iD}{k}$

N_{Pr} = Prandtl number = $\frac{c\mu}{k}$

N_{Re} = Reynolds number (pseudo) = $\frac{Dv_v\rho}{\mu}$

P = absolute pressure, lb.force/sq.ft.

c = specific heat of liquid concentrate, B.t.u./lb.

D = inside diameter of tubes.

h_i = boiling film coefficient of concentrate inside of tubes, B.t.u./(hr.)(sq.ft.)(°F.)

k = thermal conductivity of liquid concentrate, B.t.u./(hr.)(sq. ft.)(°F./ft.)

L = length of tubes, ft.

μ = absolute viscosity of liquid concentrate, lb. (mass)/(ft.)(hr.)

ρ = density of liquid concentrate, lb./cu.ft.

σ = surface tension of liquid concentrate, lb.(force)/ft.

v_v = average velocity of vapor (outlet velocity from bottom of tubes/2), ft./hr.

methods of improving

Heat transfer in evaporators of small thermocompression sea-water stills

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Interest in converting sea water to fresh water has risen sharply in the past several years because of the growing realization of the possibility of acute shortages of naturally available potable water. The subject of this paper is concerned with the thermocompression process for use in advance-base military operations. A thermocompression still operates on the principle that by raising slightly the pressure of steam evaporated from a body of water, this steam may be condensed at a temperature slightly higher than that of evaporation so that the latent heat released by condensation can be directed back to the body of water to supply the heat required for evaporation.

Scale deposition becomes more pronounced with increases in the rate and temperature of evaporation and with increases in brine concentration. Because scale deposits on the inside of evaporator tubes may increase the over-all resistance to heat transfer by 25%, or much more, it is imperative to remove the scale frequently and if

possible to prevent its adhering to the tube walls. The problem of reducing scaling remains one of the most critical problems yet to be solved in sea-water evaporation. The best method now known for reducing scaling in advance-base stills appears to be the periodic injection of citric or other acids.

Two series of runs were conducted to determine the effects of dropwise condensation and forced-circulation evaporation. One series was run with plain brass tubes ½ in. O.D., 36 in. long, 16 B.W.G., nominal composition 66.5% Cu, 33% Zn, and 0.5% Pb. Presumably film-type condensation took place on the outside of these tubes, although it is possible that mixed condensation occurred. For the second series of experiments the same type of tube was coated on the outside with a thin layer of Teflon to induce dropwise condensation. The Teflon coating was estimated to be on the average about 0.0005 in. thick. It was applied by hand spraying one coat of Teflon enamel on the tubes, and curing the enamel at 690°F. for 1½ min. in a hot-air furnace. It should be pointed out that the handspraying method of applying the coating was resorted to only for expediency; a refined technique, which is now available, undoubtedly would have produced a more uniform and possibly thinner coating. Inasmuch as Teflon has a low thermal conductivity, 1.7 B.t.u./(hr.) (sq. ft.) (°F./in.), the thinnest possible film is desirable. Thus, with a refined method of application, condensing coefficients higher than those obtained in this work might be obtained.

All runs were made with ordinary city water boiling at or near 212°F. Thus in applying the results to the design of a sea-water evaporator it is necessary to allow for the elevation in boiling point of the sea water. For the brine concentration factors used in advance-base stills, the boiling-point elevation ranges from 1.5 to 2.0°F.

Figures 1 and 2 show the results of the experiments with the heat flux plotted against the over-all ΔT and evaporating water velocity. The parameters for the two figures are identical except that Figure 1 is for film condensation whereas Figure 2 is for dropwise condensation promoted by the Teflon coating. The velocities shown on the curves are those of the evaporating water at the entrance to the tubes.

This article is a condensation of the paper given at the 1958 A.I.Ch.E.—A.S.M.E. Second Annual Heat Transfer Conference held in Chicago, Ill.

The ΔT shown in the figures is the apparent temperature difference between the condensing steam and evaporating water. The term "apparent temperature difference" is descriptive in this instance because the temperature of the evaporating water is assumed to be that corresponding to the saturation temperature of the steam above the tubes.

The following generalizations apply:

(1) At a water velocity of 10 ft./sec. the heat transfer rate is about 2½ times that obtained with natural convection regardless of the mode of condensation. At 6 ft./sec. the increase is 1½ to 2 times that with natural convection.

(2) Percentagewise, the effect of forced circulation increases as the ΔT decreases.

(3) Dropwise condensation with the Teflon coating yields increases in heat transfer of 13 to 33% over film condensation on brass, depending on the water velocity and the ΔT. The gain for natural convection boiling is 25 to 30%.

Figure 3 compares the film coefficients of dropwise and film condensation which were determined by an indirect method. Figure 3 shows that for a condensing film ΔT of 1 to 2°F., which is desired in a thermocompression still, the Teflon coating increases the coefficient about 80% over film condensation taking place on a brass tube. It should be pointed out that in plotting the curve for dropwise condensation the resistance of the Teflon film was included. Thus the curve reflects the net improvement obtainable with Teflon. The spread between the curves for film-type con-

continued

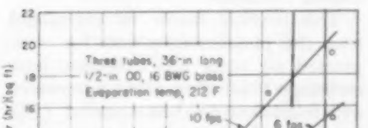

Figure 1. Relation of heat flux to over-all temperature difference and evaporating water velocity with film condensation.

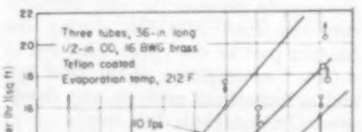

Figure 2. Relation of heat flux to over-all temperature difference and evaporating water velocity with dropwise condensation.

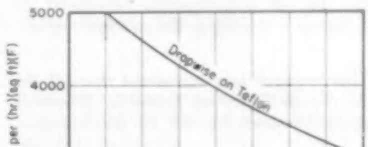

Figure 3. Comparison of dropwise and film-type condensing coefficients.

Sea water stills
continued

densation and the Nusselt equation is in line with the experience of other investigators.

The results of this investigation have demonstrated that substantial improvements in heat transfer can be expected from dropwise condensation and forced-circulation evaporation. For an advance-base still it is doubtful that the benefits of forced circulation can be utilized owing to the design criterion that in general maximum thermal efficiency should take precedence over minimum weight and first cost of the still. The pumping power required for forced circulation reduces the over-all thermal efficiency of an advance-base thermocompression still. With regard to dropwise condensation, the possibility of 25% reduction in evaporator surface while maintaining the high performance factor deserves immediate attention.

Because Teflon has a low thermal conductivity, which is unfavorable in this application, other means of promoting dropwise condensation should be considered. Other coatings, besides having lower thermal resistance than Teflon might also produce large contact angles, thereby permitting even higher condensing coefficients. Certain of the silicones are reported to be highly nonwettable and combine with water to form a film only a few molecules thick. Several organic materials such as dibenzyl sulfide have shown excellent results in maintaining nearly perfect dropwise condensation. Titanium is not easily wetted by water and could be expected to be a good dropwise promoter. In addition, titanium is resistant to attack by sea water and would thus be doubly useful in a sea-water evaporator.

The following four articles are abstracts of papers given at the 1958 A.I.Ch.E.—A.S.M.E. Heat Transfer Conference in Chicago. The complete texts will appear in Symposium Series Volume Number 24.

description and experimental results of

Two regenerative heat exchangers

E. K. Dabora, M. P. Moyle, R. Phillips, J. A. Nicholls, and P. L. Jackson
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Two pebble-type regenerative heat exchangers capable of operating at pressures and temperatures beyond the limits of commercially available equipment have been designed and constructed. These heat exchangers were required to produce stagnation temperatures of the order of 2500°R. at pressures of the order of 1000 lb./sq. in. in experiments designed to achieve a standing detonation wave.

This research was supported through the Air Force Office of Scientific Research, under Contract No. AF 18(600)-1199.

Regenerative heat exchanger theory is well established for the adiabatic (no heat loss) type of exchanger *(6)*. The design of the two heat exchangers used was made according to *(6)*, with provision of insulation and an estimate of the heat loss. However, despite these precautions, the hydrogen heat exchanger proved to be inadequate because the exit temperature remained very low during the heating part of the cycle. This led to a closer investigation of the heat loss and a theoretical analysis was developed (7) to include this loss.

According to (7), if the inlet temperature is constant and the heat-exchanger bed is at a uniform temperature lower than the inlet temperature of the gas at time zero, then the nondimensional form of equations for the bed and gas temperatures as a function of time and length of heat exchanger can be written in terms of known variables.

The friction factor as calculated from the pressure-drop data for compressed air using the hydrogen heat exchanger indicated close agreement with friction-factor data reported *(12)*.

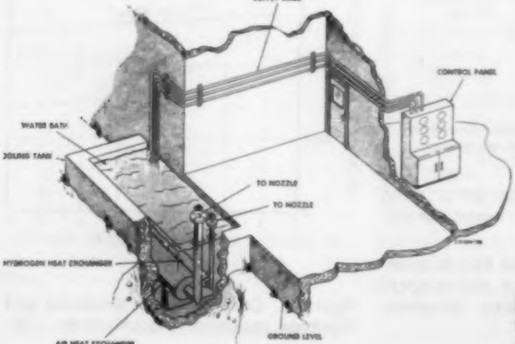


Figure 2. Physical arrangement of the heat exchangers and controls.

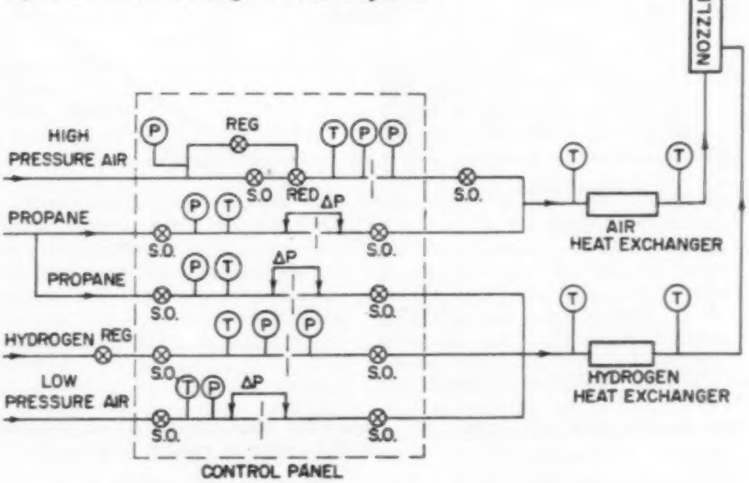
Conclusions

The effect of heat-loss parameter (product of reduced length times dimensionless heat transfer ratio) on the transient and steady-state temperature has been shown to agree with the theoretical analysis.

For this reason, a careful evaluation of this product is essential for the purpose of predicting the steady-state temperature at the exit of a regenerative heat exchanger.

Heat-transfer coefficients evaluated from the experimental results are lower than those generally found in the

Figure 3. Schematic diagram of flow system.



literature despite the fact that heat loss has been accounted for. Although no explanation could be found, it is suggested that when values of heat-transfer coefficients as obtained from the literature are used, they should at least not be considered to yield a conservative design.

In evaluating the heat capacity of the bed material, allowance should be made to include at least part of the heat capacity of the insulation. What this part should be depends upon the expected temperature distribution in the insulation.

NOTATION

a=viscous resistance coefficient, /sq.ft.
b=inertial resistance coefficient, /ft.
C=heat capacity of heat-exchanger bed material per unit volume, B.t.u./(cu.ft.)/(°F.)
c_p=specific heat of fluid at constant pressure, B.t.u./lb. (mass)°F.
G=mass rate of flow per unit area, lb.(mass)/(sq.ft.-sec.)
h=heat-transfer coefficient between fluid and bed material, B.t.u./(sec.)(sq.ft.)(°F.)
I_o ()=modified Bessel function of the first kind and zero order
l=b/a=characteristic length, ft.
ΔP=pressure drop, lb.(force)/sq.ft.
$Pr=cp\mu/k$=Prandtl number
$Re=lG/\mu$=Reynolds number
s=heat-transfer surface area of bed material/unit volume of bed material, sq.ft./cu.ft.
s_o=heat-loss surface area of exchanger/unit volume of bed material, sq.ft./cu.ft.
St=shl/Gcp=Stanton number
T=fluid temperature, °F.
T_i=fluid inlet temperature, °F.
t=bed-material temperature, °F.
t_o=bed-material temperature at zero time, °F.
t_s=temperature of surroundings, °F.
U_o=overall-heat-transfer coefficient to surroundings based on area s_o
V=fluid velocity, ft./sec.
w=mass flow rate, lb. (mass) /sec.
x=heat-exchanger length, ft.

Greek Letters

$\alpha=s_o\, U_o/sh$ nondimensional heat-transfer ratio
δ=nondimensional bed temperature
$\eta=sh\tau/C$=reduced time
θ=nondimensional fluid temperature
μ=viscosity of fluid, lb. (mass) /ft./sec.
$\xi=shx/Gc_p$ reduced length of heat exchanger
ρ=specific weight of fluid, lb. mass/cu.ft.
τ=time, sec.

Subscripts

ss=steady-state
$_{1,2}$=refers to two different stations along heat exchanger

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Heat transfer and pressure drop of air in forced convection across triangular-pitch banks of finned tubes

Dennis J. Ward* and Edwin H. Young
University of Michigan, Ann Arbor, Michigan

This investigation involved the study of the effects of tube geometry on the heat transfer and pressure drop characteristics of triangular pitch tube banks containing smooth, integral, helically finned tubes with air drawn by forced convection in crossflow through the banks. Seven finned tube banks ranging from four to eight rows deep were studied with air velocities from 200 to 3,000 ft./min. based on the minimum cross section of the tube banks. The tubes used in the investigation ranged from ⅝ to 2¼ in. diam. over the fins. Equilateral triangular pitch arrangements were used with tube spacings equal to the nominal fin diameters plus 3/16 in. for all tube banks.

Correlation of heat transfer data

Conventional equations modified for fin dimensions can be solved for h_o, the mean outside air film coefficient as shown in Equation (5), page 88.

The data for units 6, 7, and 8 were corrected to be equivalent to banks with six rows of tubes before the regression analysis was run. Equation (5) is limited to banks having six rows of tubes.

Equation (5) indicates that the mean air film heat transfer coefficient

continued

* *Dennis J. Ward is at present with Universal Oil Products.*

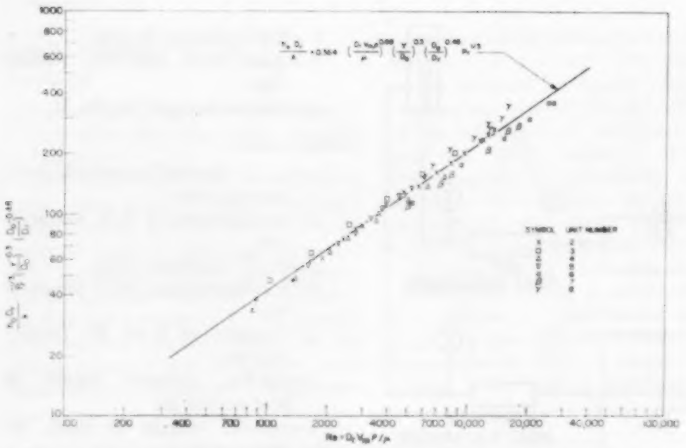

Figure 8. Comparison of finned tube heat transfer data with least mean square fit curve.

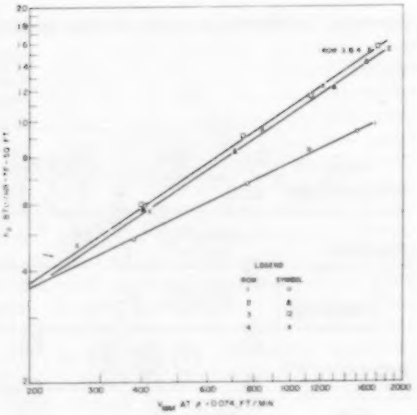

Figure 10. Heat transfer curves obtained for the individual rows of unit number 8.

Forced convection

continued

is strongly dependent on the value of the root diameter, moderately dependent on the thickness of the fin, slightly dependent on the outside diameter, and independent of the spacing between adjacent fins. The experimental finned tube heat transfer data are graphically compared with Equation (4) [dimensionless form of Equation (5)] in Figure 8. The data have a maximum spread of +20% and −15% with an average deviation of ±7% from the correlating line. The row-to-row heat transfer performance was investigated using finned tube unit number eight. The data are summarized in Figure 10.

$$h_o = \frac{0.364k\ (V_m\rho)^{0.68}}{\mu^{0.68}}\ (Pr)^{1/3}\left(\frac{1}{D_r}\right)^{0.77}\ (Y)^{0.3}\ (D_o)^{0.15} \qquad (5)$$

Correlation of pressure drop data

The air-side pressure drop data for the eight units can be represented by equations (for $p_{air} = 0.074$) of the form:

$$\frac{\Delta P}{n} = a(V_{max})^{\beta} \qquad (6\text{-A})$$

where a has a value characteristic of each unit, ranging from 0.95 to 3.5 for most of the units tested, but not all, and β ranges from 1.5 to 1.9 over the velocity range studied.

NOTATION

D_o=outside diameter of bare tube or diameter over the fins of finned tubes, ft.

D_r=root diameter of tube, ft.

h_o=mean outside air film coefficient, B.t.u./hr.-sq.ft. (external area) -°F.

k=thermal conductivity of air, B.t.u./(hr.)-(°F./ft.)

n=number of rows of tubes normal to air flow

Pr=Prandtl number, dimensionless

V_m or V_{max}=velocity of air at minimum cross section, ft./min.

Y=mean fin thickness, ft.

μ=viscosity of air at bulk stream temperature, lb./(ft.)(hr.), μ_{w} at tube wall temperature

ρ=air density, lb./cu.ft.

ΔP=total air side pressure drop, lb./sq.ft.

$a\beta$=abstracter's constants

Heat transfer rates to boiling Freon 114 in vertical copper tubes*

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Heat transfer rates from condensing steam to boiling Freon 114 were measured in vertical copper tubes of ⅝-, ⅜-, and ¼-in. diam. to determine where the assumption of uniform heat flux could be safely used and how tube length, tube diameter, flow rates, pressure, and temperature difference affected uniformity. Heat transfer rates were uniform along the length of the tube up to a temperature difference of 20°F.; above this temperature difference 12.5% of the area transferred up to 75% of the total heat.

The vertical-tube Freon boiler was designed so that the condensing steam could be collected at 1-ft. intervals along the entire 8-ft. length of copper tube. Heat transfer rates were measured as shown in Table A on the next page.

The lowest steam-to-Freon temperature difference that could be obtained was approximately 8°F. This limit was established because heat loss due to ambient temperature would not allow the system to maintain pressure at the low heat transfer rate. At low temperature differences the heat flux was

* *This work performed under AEC Contract AT-(33-2)-1.*

Table A

Variables	Ranges
Steam-to-Freon temperature difference	10 - 75°F.
Tube size, O. D.	¼-in. - ⅜-in. - ⅞-in.
Freon pressure	60, 75, 90 lb./sq. in. gauge
Freon flow rates	190,000 - 509,000 lb./(hr.) (sq.ft.)

uniform along the entire length of the boiling section. As the steam-to-Freon temperature difference was increased, the total heat flux increased proportionally, still remaining uniform along the tube, up to a temperature difference of about 20°F. Above this temperature difference the total heat transferred began to decrease slightly, upsetting the equilibrium between condensing steam in the steam chest and steam flow through the throttling valve. This caused the steam pressure to increase in the chest, increasing the steam-to-Freon temperature difference. When a new equilibrium was reached, the steam-to-Freon temperature difference was 25°F. or higher, and the heat flux was no longer uniform along the tube. Under these conditions the lower portion of the tube was still maintaining nucleate boiling, with the bottom 12-in. section, which was 12.5% of the surface area, transferring 50 to 75% of the total heat. Figure 4, a typical plot of ΣB.t.u. vs. the position up from the bottom of the exchanger, shows heat flux distribution over a range of steam-to-Freon temperature differences.

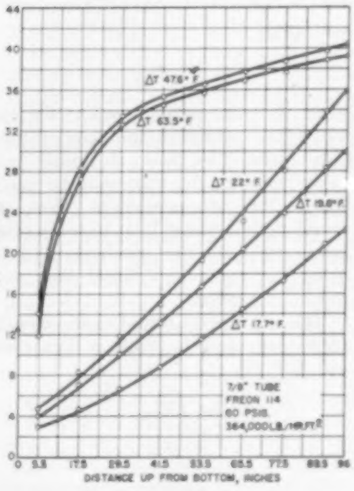

Figure 4. Σ B.t.u./hr. vs. position in tube.

Condensing heat transfer within horizontal tubes

W. W. Akers, H. A. Deans[1], and O. K. Crosser[2] The Rice Institute, Houston, Texas.

This investigation studied the effect of vapor velocity, liquid loading, and physical properties of the fluid on the condensing coefficient of a vapor inside a horizontal tube.

1. *Princeton Univ.*
2. *Univ. of Okla.*

The data are the results of a series of tests in which the average condensing coefficient, h, was determined as a function of the mass flow of the vapor, G, in the tube at a constant tube wall temperature and a constant pressure. The average condensing coefficient for Freon 12 and propane as a function of the average vapor velocity is shown in Figure 3 to illustrate the general behavior of the data.

In general, h as a function of G exhibits nearly linear behavior at high vapor velocities. As the velocity is decreased a break in the curve is found

continued

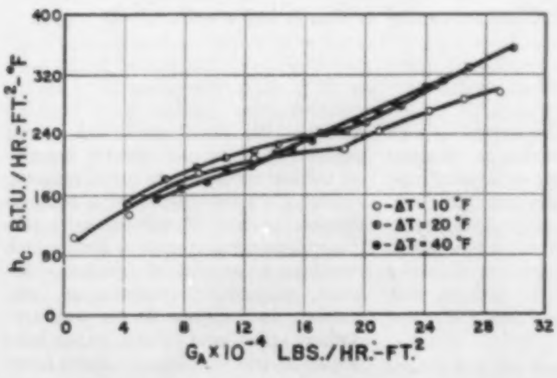

Figure 3. Condensing coefficients for Freon-12. P=400 lb./sq. in. abs.

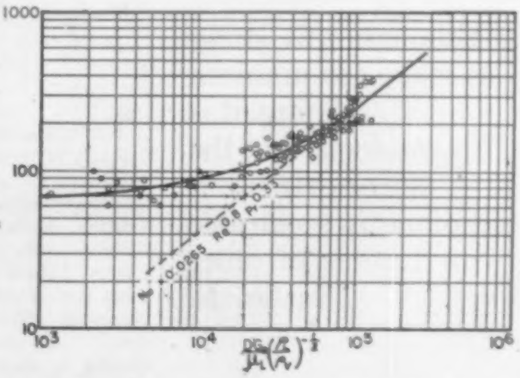

Figure 4. Correlation of condensing coefficients for propane and Freon-12 in a horizontal tube.

Horizontal tubes
continued

which is more pronounced at the intermediate pressures and temperature differences. The flow of liquid and vapor through the tube may be combined into an equivalent flow of liquid. Single-phase heat transfer relations correlate the condensing data using the equivalent liquid flow and liquid properties.

This equivalent liquid mass velocity could be used to form a Reynolds number:

$$Re = \frac{DG_E}{\mu_L} \qquad (10)$$

This Reynolds number would describe the fluid dynamics of the system and the heat transfer coefficient should be correlated by the usual equations for single phase flow:

$$Nu\, Pr^{-m} = A\, Re^{n} \qquad (11)$$

Figure 4 shows $m=1/3$ to be satisfactory. Above $Re=5\times10^4$ Equation (11) becomes:

$$Nu\, Pr^{-1/3} = 0.0265\, Re^{0.8} \qquad (12)$$

below this point:

$$Nu\, Pr^{-1/3} = 5.03\, Re^{1/3} \qquad (13)$$

Conclusions

The broken line on Figure 4 is the single phase heat transfer correlation according to Eckert (6). The data correlate very well and the agreement with the equation from Eckert is striking. For condensation inside a tube, the shear due to the velocity of the vapor is dominant. The liquid loading and temperature difference across the film have no effect upon the heat transfer coefficient at high vapor rates, and a small effect below the transition point.

NOTATION

A=empirical constant in general equation
D=tube diameter
g=mass velocity
h=average condensing coefficient
m=exponent of Pr
n=exponent of Re
Nu=Nusselt number
Pr=Prandtl number
Re=Reynolds number
μ=viscosity
Subscripts
L=corresponds to liquid or condensate
E=corresponds to equivalent or similar liquid

LITERATURE CITED

6. Eckert, E. R. G., "Introduction to the Transfer of Heat and Mass," p. 115, McGraw-Hill (1950).

The joint A.I.Ch.E.—A.S.M.E. Heat Transfer Conference, where all the foregoing papers were given, is one of the major heat transfer events of the year. Next year's Third Annual Joint Heat Transfer Conference will be held August 9 to 12 at the University of Connecticut, Storrs, Connecticut.

Metal refining by Solvent extraction of leach slurries

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National Lead Company of Ohio, Cincinnati, Ohio

Although this study was made for uranium refining, it is considered that the slurry extracting technique is applicable to a range of other materials.

The current requirements for new metals to meet increasingly stringent demands for materials of construction have provided the impetus for application of chemical engineering techniques to the field of extractive metallurgy. Liquid-liquid solvent extraction has been a particularly valuable tool. Treybal (65) Schlechten (56) and Coffer (10) have published recent reviews showing the general breadth of solvent extraction in metal refining. Culler (12) has presented a comprehensive review of solvent extraction for reprocessing of nuclear fuels which involves separation of uranium, thorium, plutonium, protactinium, aluminum and various fission products. Others cited later in this paper have explored and developed various facets of refining and reprocessing nuclear fuel by solvent extraction.

** B. G. Ryle is now associated with Parker Pen Company, Janesville, Wisconsin.*

The advantages of hafnium-free zirconium for nuclear reactor fabrication have resulted in the development and application of two solvent extraction processes for zirconium-hafnium separation. The process using methyl isobutyl ketone (hexone) with ammonium thiocyanate for separation of the chlorides has been described by Ramsey and Whitson (49) and by Shelton, Dilling and McClain (60). The separation of the hafnium and zirconium nitrates with tributyl phosphate has been reported by Beyer and Peterson (4), Hudswell and Hutcheon (25), Hure and R. Saint James (27), Alcock, *et al.* (1) and on a production scale by Keller and Zonis (31). Levitt and Freund (38) have published distribution coefficients for tributyl phosphate extraction of zirconium from the aqueous chloride solution.

Development of a process of refining tantalum and niobium (columbium) by methyl isobutyl ketone extraction from hydrofluoric acid leach liquor has been reported by Koerner, Smultz and Wilhelm (34). An extension of this work including results of tributyl phosphate extraction tests was conducted by Pierret and Wilhelm (46). Separation of niobium and tantalum with methyl isobutyl ketone from hydrochloric, hydrofluoric and mixed hydrochloric-hydrofluoric acid leach solutions has also been extensively investigated and reported by Werning *et al.* (69, 70) and by Higbie and Werning (24). A patent was recently issued to Hicks, *et al.* (23) for separation of tantalum from niobium with di-isopropyl ketone and an aqueous HF-mineral acid leach solution. Faye and Inman (16) reported a process for niobium-tantalum separation using methyl isobutyl ketone and a hydrofluoric-nitric acid leach solution.

Several processes for separation of cobalt and nickel have been investigated and reported in recent literature. Sharp and Wilkinson (58) used ammonium thiocyanate and hexone to produce nickel-free cobalt from aqueous nitrate solution in laboratory tests. Griffith, Jasny and Tupper (18) reported pulse column extraction performance in separation of cobalt and nickel chlorides with ammonium thiocyanate and hexone. Kylander and Garwin (36) determined spray column performance for cobalt-nickel separation using capryl alcohol as an extractant with an aqueous solution of the metal chlorides. Schlea and Geankoplis (55) reported the results of extensive tests of various organic solvents for separation of iron, cobalt and nickel sulfates.

The separation of zinc chloride from zinc sulfate by solvent extraction with furfural has been described by Garwin and Winterbottom (17). Tributyl phosphate extraction of scandium, thorium and zirconium from chloride and nitrate systems was investigated by Peppard, Mason and Maier (42). Data for separation of thorium, uranium, protactinium, yttrium, lanthanum, gadolinium, neodymium, europium, terbium, dysprosium, holmium, erbium, thulium, lutetium, cerium, praesodymium, samarium, strontium, barium and plutonium with various phosphate ester extractants from chloride and nitrate solutions have been reported by a number of investigators (22, 33, 41, 43, 44, 54).

The application of solvent extraction to refining of thorium has been described briefly by Spedding and Kant (61), by Taylor, Ross and Davis (63) and by Calkins and Bohlmann (9).

Examples of the rapid introduction of solvent extraction processes for production of uranium ore concentrates in the Colorado Plateau area have been reported by Ellis *et al.* (14), Shaw and Long (59), Ross (50), Koslov and Black (35), and Hazen and Henrickson (21). These processes involve the use of amines or alkyl phosphates as extractants with sulfuric acid leach slurries or liquors.

History

Numerous applications of solvent extraction to the refining of metals have been reported in recent literature, and use of tributyl phosphate in uranium refining by liquid-liquid extraction has been described by several authors (2, 3, 28, 32, 67). Early development work on the application of tributyl phosphate slurry extraction to uranium purification was reported by Runion, Ferguson, Ellison, Yeager and Jealous (15, 29, 51, 52). Additional phase distribution and solubility data for the tributyl phosphate extraction of uranyl nitrate from aqueous nitric acid solution have been presented in subsequent reports (5, 7, 37, 39, 68). The employment of organic diluents for the tributyl phosphate solvent and the physical properties of the solutions as a function of temperature, diluent, tributyl phosphate, uranium and nitric acid concentrations have been investigated (6, 8, 45). A survey of literature on tributyl phosphate as a uranium extractant has been reported by Wright (72). Since the Van Dijck patent (66) on the pulsed perforated plate column and its application to uranium processing (57), numerous accounts on column performance tests and design principles have been published (11, 13, 19, 30, 47, 48, 62, 64, 71).

Nitrate, chloride and fluoride acids and salts are used for scrubbing and re-extraction in these milling processes.

In each of the processes described above, acid leach liquors are used which require special corrosion resistant materials of construction for equipment fabrication. By virtue of the high value placed upon the product, high degrees of recovery are necessary for each process step. Rigorous purity specifications are generally imposed upon the product. These are basically the same criteria imposed upon the solvent extraction system of the uranium refinery. A slurry extraction system has been developed which meets these criteria yet substitutes a small polishing filter on the purified re-extraction product stream for the large filtration system that would be required for preparation of a clarified solvent extraction feed. Various equipment and operating problems associated with slurry extraction have been encountered and overcome. It is believed that the basic features of slurry extraction technology as developed for uranium refining may be applicable to problems encountered in these newer fields of metal refining by solvent extraction.

The primary purpose of this article is to discuss the general principles involved in refining uranium by slurry extraction of ore concentrates and high-grade ores. A description of the digestion and extraction techniques is presented with the unusual features peculiar to slurry extraction being stressed. The theoretical aspects of the mechanism of uranium extraction in the tributyl phosphate-uranyl nitrate system have been presented in recent publications *(20, 39, 40)* and will not be repeated here. It will suffice to say that the introduction of solid particles into the system has no known effect on the chemical equilibrium which normally occurs in the clarified stream system. However, with respect to the physical properties of the extraction system and process stream handling, solid suspensions have a very real effect.

Feed slurry preparation

The ore or ore concentrate was first ground *(2)* (a) to facilitate sampling for assay purposes, (b) to facilitate conversion of the uranium values to a soluble extractable form during the digestion, and (c) to yield a final slurry which can be easily handled through the extraction system.

The digestion operation was conducted batchwise with calculated quantities of ore, nitric acid, and

continued

water. Each different ore or concentrate was pretested in the laboratory in order to determine (a) the ore to acid weight ratio, (b) the nitric acid concentration, and (c) the digestion temperature to be used in order that the final slurry would meet the established uranium and acid concentrations with a minimum of concentration adjustment being necessary after the digestion cycle was completed. In the case of some low-grade ores which contained a high percentage of acid insoluble components, the uranium concentration (not the nitric acid) was reduced in order to reduce the solids content of the final slurry. Slurries containing in the neighborhood of 15% solids by settled volume have been satisfactorily processed. After the digestion cycle was completed, the slurry was analyzed for uranium and nitric acid and was pumped to the feed hold tank.

Refining system

The refining system is shown in Figure 1 *(3)*.

It consisted of pulsed, perforated plate columns together with the necessary auxiliary equipment to handle the feed slurry, raffinate slurry, solvent recycle, and product stream. The feed slurry first passed through a primary extraction column where the uranyl nitrate was preferentially complexed and extracted from the feed slurry by the tributyl phosphate in the solvent stream. The resulting uranium-laden organic extract from the primary extraction was scrubbed with a small amount of water in a partial reextraction, or scrubbing process to separate the impurities dissolved in the primary extract product. The uranyl nitrate was then stripped or reextracted from the purified organic extract stream from the scrubbing step to give a high-purity aqueous uranyl nitrate product solution.

Primary extraction

The feed system was designed to handle slurries containing a relatively high solids content and having a high settling rate.

The feed hold tank was equipped with a recycle loop from the tank extending to the top of the extraction column and returning. A high-velocity centrifugal pump continuously circulated the slurry through the loop at a rate sufficient to keep the solid particles suspended thereby supplying a relatively homogeneous feed stream to the extraction column. The slurry was fed to the columns through a take-off line located at the top of the loop, the flow rate being controlled by an air-operated, diaphragm valve in the line. It was found necessary to maintain a constant back-pressure of about 10 lb./sq. in. gauge on the slurry feed loop to provide effective operation.

The extraction column contained 1/16-in. thick stainless steel plates, perforated with 3/16-in. holes punched on 3/8-in. centers in an equilateral triangular configuration (Figure 2). The plates were spaced at 2-in. intervals throughout the effective extraction height of the column. Disengagement chambers with expanded diameter were located at the top and bottom of the column. The aqueous feed slurry was introduced at a point just above the top plate. It has been found that specially designed spray nozzles are not required on the slurry inlet; therefore to minimize feed line plugging, a straight pipe inlet was used. The recycle stream from the scrub column was combined with the feed stream as it entered the column. The organic extractant (a solution of tributyl phosphate in an inert purified kerosene diluent) was introduced through the pulse generator transfer line rather than directly into the bottom of the column. In this way the pulse transfer line was kept filled with the fresh, comparatively nonacidic organic phase, thereby reducing the corrosion in the pulse generator.

By operating the primary extraction column with the organic phase continuous and the aqueous phase dispersed, the deposition of the solids on the plates was minimized. The combined liquid phases were pulsed through the stationary perforated plates in the column. Both piston-type generators and Teflon bellows-type pulse generators have been used. Although the bellows-type units are inert to nitric acid corrosion, the bellows have a shorter life span as they tend to fail mechanically under extended operation. Modification of the bellows design has resulted in units which have tested between five and six million cycles before rupturing.

The extraction column was operated with a constant organic extractant flow rate and with a feed stream flow rate controlled so as to maintain a constant uranium saturation level in the organic product stream. Since the nitric acid and other contaminants present in the organic extract stream contribute little to its specific gravity in comparison to that contributed by the extracted uranium, it was possible to maintain a constant uranium level in the extract stream by controlling its specific gravity. The system was instrumented to control automatically the feed stream flow rate to provide an extract of uniform uranium concentration. A differential pressure cell located in the extract stream overflow line sensed and continuously recorded the specific gravity. Any variation from the density control set point automatically changed the feed stream flow rate and returned the product stream to the desired uranium concentration. The corresponding feed stream flow rate was measured and recorded. Venturi, orifice, and induction-type flow meters have been used for this purpose.

Difficulties have been observed in this type of control system. There is a considerable time-lag between the

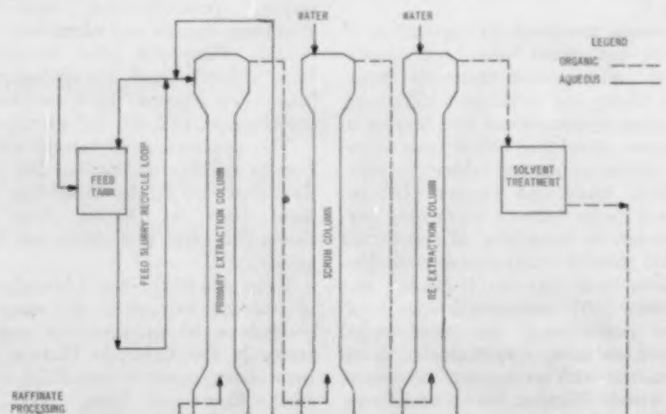

Figure 1. Pilot plant slurry extraction system.

time that a variation in the product stream density is sensed and the time that the corrective change in the feed stream flow rate takes effect. This is primarily due to the fact that considerable time is required to change the uranium concentrations in both phases in the column. It has been found that variation in the specific gravity of the product stream is generally due to fluctuations in feed concentration and that these can be anticipated. Under certain conditions manual adjustment of the feed stream flow rate to compensate for the product stream specific gravity variations proved more effective in maintaining a uniform product concentration. A companion article *(53)* reports the results of a development project on the application of gamma radiation density gauging to extraction column measurement and control in an effort to overcome this instrumentation problem. The basic aqueous to organic flow rate was selected to provide a product stream with a high uranium saturation level yet maintaining a negligible uranium concentration in the raffinate stream.

In the case of raffinates containing a high percentage of solids, the solid particles tend to adsorb and entrain quantities of the tributyl phosphate-kerosene solvent greatly in excess of that carried by the raffinate streams from the processing of preclarified aqueous feeds. It was found that contacting of the raffinate stream with kerosene in a single stage mixer-settler system reduced the tributyl phosphate concentration to less than 0.2 g./l., a tolerable level. This operation may be desirable for either or both of two reasons: (1) recovery of the excess entrained tributyl phosphate for return to the system and, (2) as a safety measure to avoid possible explosive reactions which might otherwise result during high temperature processing of the raffinate for nitrate recovery.

Scrubbing

The scrub column differed physically from the extraction column only with respect to column diameter and plate geometry.

The plates had ⅛-in. holes on ¼-in. centers to provide a 23% free area. Column height, plate hole pattern, and plate spacing were the same as in the extraction column. Operation with the aqueous phase as the continuous phase appears to give better column performance.

The organic product stream from the extraction column entered the scrub column through the pulse transfer line and traveled up through the column where it was contacted by a downward flow of deionized water. During the scrubbing operation, practically all of the impurities and free nitric acid were transferred from the organic phase into the aqueous phase. A considerable quantity of uranium was also transferred with the impurities, therefore, the aqueous phase was recycled to the aqueous feed stream to the extraction column for uranium recovery. The scrubbed organic stream was fed to the bottom of the reextraction column.

Reextraction (stripping)

Reextraction was accomplished in essentially the same manner as the scrubbing except for making the organic solvent the continuous phase. Whereas in the scrub column the organic phase was contacted with water at a flow rate just sufficient to remove essentially all the impurities and result in only a partial extraction of the uranium, in the reextraction column the aqueous to organic flow ratio was increased to the point where nearly all of the uranium values were removed from the now purified organic stream. After being essentially depleted of uranium, the organic phase was pumped to the solvent clean-up system for treatment and return to the extraction cycle.

The aqueous uranyl nitrate product stream was passed through a sintered stainless steel filter to remove the last traces of suspended impurities. Finely divided, low density solids such as may be found in feed slurries (i.e., silica and carbon) are readily transferred between the aqueous and the organic phases in the pulse columns and therefore may be carried across the columns' interfaces and through the system. Not only are silica and carbon impurities in themselves but they are excellent adsorbers of other metallic impurities.

Solvent clean-up

The organic phase from the reextraction columns in extended operation may contain many impurities introduced during the extraction process which must be removed. The residual uranium must be removed to prevent its later loss through the raffinate stream from the extraction column; the hydrolysis degradation products of the tributyl phosphate, namely, the *di* and *mono* derivatives which will hinder the extraction process if present in greater than trace concentrations, must be removed; and the residual entrained solids must be removed to prevent excessive build-up and resulting product contamination.

A solvent clean-up system is used to meet these requirements. The organic stream was washed with a dilute aqueous sodium carbonate solution and then with water to remove residual uranium, nitric acid, and hydrolysis products. Entrained solids may be removed by centrifugation. These operations reduce the build-up of harmful impurities and permit continuous recycling of the extractant.

Figure 2. Perforated plate installation in glass wall section of pilot plant column.

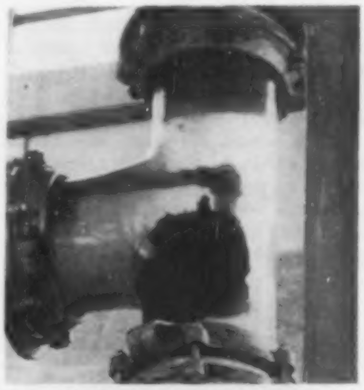

Figure 3. Accumulation of fine solid particles (crud) at interface at top of pilot plant scrub column.

Operational difficulties

Processing of slurry feed presented a number of difficulties other than those which have been previously

continued

stated. An inherent problem of the slurry processing system is the ease with which finely divided solid particles are physically entrained in the organic phase and subsequently dispersed throughout the system. The solid particles preferentially gather at the column interfaces building up a considerable band of "crud" as shown in Figure 3. In addition to physically contaminating the aqueous product stream if not removed by filtration, these particles promote chemical contamination and tend to reduce extraction efficiency and column performance.

Chemical contamination may be caused by excessive entrainment of surface-adsorbed metallic impurities into the scrub column. This may lead to contamination levels which are in excess of that which can effectively be removed by the purification process and thereby result in chemical contamination of the product. In the case of free carbon, if too great a concentration is permitted in the feed stream, product contamination may occur even with a filtration operation.

Silica, which is a major component of all naturally occurring ores and which is present in relatively large quantities even in preprocessed concentrates, affects both the product purity, and the column operations.

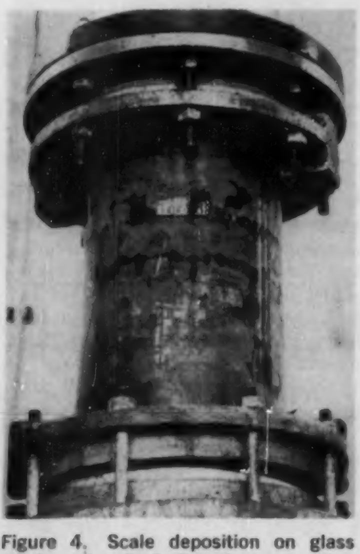

Figure 4. Scale deposition on glass section of wall of pilot plant extraction column.

Product contamination by silica is due to physical entrainment in the same manner as in the case of carbon. In addition, soluble forms of silica tend to promote emulsion formation in the pulse columns thereby reducing the column throughput. These effects can be minimized by increasing the acid concentration, temperature, and cycle time during the digestion process in order to convert the silica to the insoluble form and to promote aggregation of the individual particles. The aggregates can be removed in the product filtration operation.

The formation of heavy interfacial crud bands has two harmful effects on the extraction system. It presents a physical barrier at each column interface which may reduce over-all mass transfer in that particular column zone and hinder phase separation. In addition, the solids may interfere with the normal operation of the phase interface float controls, such interference causing upsets in the column operation. The interface controls may be equipped with flushing lines so that they can be water purged periodically to remove the solids build-up. The installation of drain lines at the column interfaces for intermittent crud removal has also been considered.

The presence of certain materials which precipitate during the course of extraction may result in deposition of solids on the walls and plates of the primary extraction column as a scale. An example of scale deposition is shown in Figure 4. This may be avoided by limiting the concentration of these precipitate-forming materials in the feeds *(3)*.

Example of slurry extraction performance

The general principles involved in slurry extraction of uranium as outlined have been applied in a test of a concentrate containing approximately 70% uranium in the National Lead Pilot Plant at Fernald *(26)*. The significant process conditions used in this test have been summarized as follows to illustrate in more detail the performance of the extraction described here.

Approximately 1,700 lb. of concentrate was added at a rate of 500 lb./hr. to 10.1*N* nitric acid at 70°F. (initial conditions) raising the temperature to 120°F. and gave a slurry containing 423g.U/liter and 6 *N* HNO_3 after digestion at 190°F. for 2 hr. This was diluted with water and nitric acid to produce an extraction feed slurry containing 195 g.U/liter and 2.9 *N* HNO_3. Approximately 310 gal. of 60% HNO_3 was used/ton of concentrate.

The feed slurry was cooled to 100° F. and pumped to the primary extraction column (pulsed perforated plate column) where it was contacted countercurrently with the organic solvent containing 33.5% (by volume) tributyl phosphate in a kerosene diluent. A ¾-in. amplitude pulse at 65 cycles/min. was used in this column with the aqueous slurry dispersed in the continuous organic solvent phase. The aqueous feed to organic solvent ratio (volume) of 0.51 gave an effective aqueous to organic feed ratio of about 0.64 in the primary extraction column when the recycled aqueous raffinate stream from the scrub column

Table 1.—Spectrochemical Analysis of Sample of Pilot Plant Aqueous Uranyl Nitrate Reextraction Product (26)

Impurity	Concentration*
Al	<4
B	<0.2
Ba	<5
Bi	<1
Ca	10
Cd	<0.2
Co	<2
Cr	<4
Cu	<1
Fe	10
Li	<5
Mg	1
Mn	<4
Mo	<4
Na	120
P	<20
Ni	<2
Pb	<1
Si	14
Sn	<1
V	<20
Zn	<20

* p.p.m., parts impurity per million parts uranium.

Table 2.—Laboratory Batch Extraction Equilibration Data (26)

Stage No.	Uranium concentration, g./l. Organic phase	Aqueous phase
Sample A		
1	115	91.5
2	77.6	12.2
3	14.4	0.75
4	5.0	0.33
5	0.28	0.049
Sample B*		
1	115	87.5
2	72.4	12.0
3	12.3	1.0
4	4.3	0.36
5	0.24	0.072
6	0.072	0.019

* Sample B was prepared from uranium concentrate produced under slightly different conditions from sample A from the same source. Tests showed only a minor performance difference between the two samples.

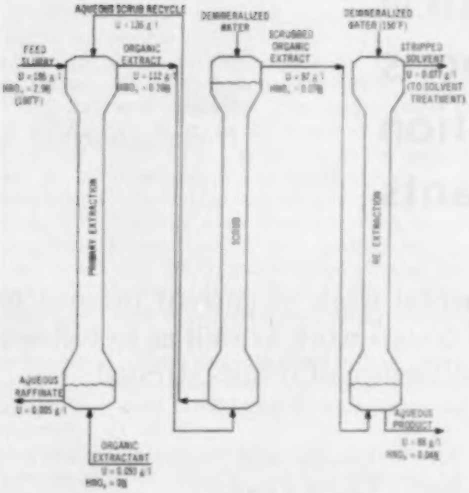

Figure 5. Sample set of stream analyses from pilot plant Test (26).

is considered. A total volumetric feed rate of 1,086 gal./(hr.) (sq. ft.) was reported for this column.

The scrub column was operated with a ⅜-in. pulse amplitude at 50 cycles/min., with the organic phase dispersed in the continuous aqueous phase and with a total volumetric feed rate of 750 gal./(hr.) (sq. ft.).

A jet-mixer column of the type described by Runion and Yeager *(52)* was used for reextraction because of its availability. An aqueous (150° F.) to organic flow ratio of 1.15 was used with a dispersion of the aqueous phase in the continuous organic phase. Total flow rates of the order of 1,420 gal./(hr.) (sq.ft.) were used.

Demineralized water was used for scrubbing and reextraction. A sample set of stream analyses is shown in Figure 5 and a spectrochemical analysis of a sample of the aqueous product is listed in Table 1.

Laboratory tests of a sample of the feed slurry determined the undissolved solids to amount to 7.9 g./liter of slurry and to assay 0.18% U representing a dissolution or leaching efficiency of over 99.99%. The extraction recovery was also over 99.99%. Laboratory batch extraction tests indicated a similar degree of recovery as seen in Table 2.

Analysis of the demineralized reextraction feed water identified it as the source of the sodium contamination of the aqueous uranyl product. Otherwise, a high degree of purity was achieved in this test with a uranium recovery of 99.99%.

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some aspects of Hydrocarbons in air separation plants

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A report on experimental work of current interest to people engaged in air plant process and design work as well as to technical supervisors of air plant operation. Significance of results stressed.

The purpose of this article is to report experimental results of air plant process and design work and its significance to air-plant application. Specifically, the behavior of nitrogen oxide and its susceptibility to explosion was investigated, and an attempt was made to answer the following questions.

1. Is it possible that chemical compounds of nitric oxides and hydrocarbons, or those of ozone and hydrocarbons, will be formed in the main condenser of an air-separation plant and then become a cause of explosion?
2. In what way does the probability of explosion of the hydrocarbons depend on the energy that starts explosions, and how does this probability change if ozone and/or nitric oxides are added to the mixture?
3. To what extent will the solutions of hydrocarbons in liquid oxygen react in a primer cap explosion at 90°K.?
4. What are the admissible hydrocarbon contents in air?

Nitric oxides and hydrocarbons (Tables 1 and 2)

The compounds of oxides of nitrogen and hydrocarbons known in the literature are high boiling substances some of which react acidly. Therefore, in air-separation units such substances would, mainly at comparatively high temperatures such as in a regenerator, be almost completely condensed or washed out by lye if purification by lye is employed. In the tests considered here, the following points were examined:

1. Whether at room temperature and at partial pressures between 0.1 and 1 atm. abs., such compounds are formed out of the gas, and what are the properties of these reaction products.
2. Whether at lower temperatures of 90° K., or 160° K. hydrocarbons, oxides of nitrogen, and oxygen react chemically.

Unsaturated hydrocarbons, oxides of nitrogen and oxygen were enclosed in varying proportions in glass bulbs of about 1 liter vol. at room temperature and at a total pressure of about 1 atm. abs., for 2 to 7 days were kept in the dark or exposed to daylight (Table 1). In most cases the formation of yellow oil droplets was observed. Only small part of the hydrocarbons present at the beginning was found again. The oils proved to be less sensitive to mechanical impact when mixed with liquid oxygen than the pure hydrocarbons from which they were produced. The oils have boiling points of about 80 or 90° C.; they resinify at 120° C.; and have a decomposition pressure of about 5-7 mm. Hg at 20° C. Thereby oxides of nitrogen are split off into the gas phase. The supposition is that these substances can be entirely dissociated if in the gas phase the partial pressure of NO is in the range of parts per million. The high boiling points, and the easy disintegration of the oils, make it most unlikely that they ever reach the main condenser and become a cause of explosion there.

In another experiment, liquid C_2H_4 and solid NO_2 were mixed and held at 160° K. for 12 hr. Then, after the

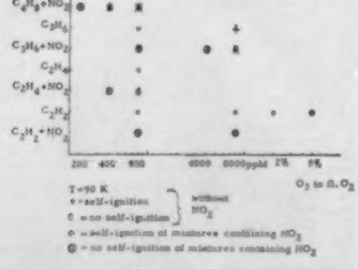

Figure 1. Self-ignition of condensed hydrocarbons in liquid oxygen with ozone and NO_2 at T = 90°K.

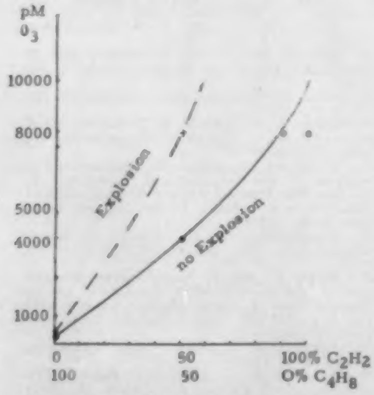

Figure 2. Self-ignition of C_2H_2—C_4H_8 — NO_2 mixtures at 90°K. caused by oxygen with ozone.

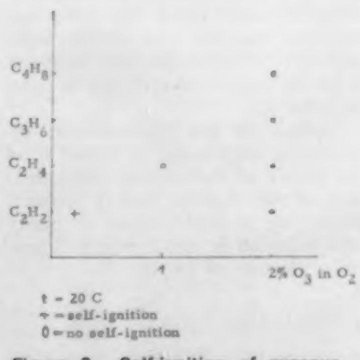

Figure 3. Self-ignition of gaseous hydrocarbons at room temperature caused by oxygen with ozone.

evaporation of the ethylene and of excess NO_2, a small drop of a yellow oil was left in the vessel which, in the presence of liquid oxygen, could not be exploded by mechanical impact (Table 2).

In order to learn whether at 90° K. the reaction velocity is sufficient for nitrification of hydrocarbons, in a number of tests some hydrocarbons (C_2H_2 or C_2H_4 or C_3H_6 or C_4H_8) were enclosed in glass bulbs together with 20 to 50 cc. of NO_2 or NO. Five cc. liquid O_2 were added at 90° K, and the mixture held at this temperature for 2 to 7 days. Then, by means of re-evaporation at low pressure the remaining quantities of the original hydrocarbons were separated and measured. Without exception, practically no difference was found between the quantities of original hydrocarbons and final ones. Reaction products, as observed at room temperatures, could not be found (Table 2). The conclusion is therefore acceptable that chemical compounds of nitric oxides and hydrocarbons cannot be formed in the bath of liquid oxygen of a main condenser.

Ozone and unsaturated hydrocarbons in presence of oxygen (Table 3, Figures 1-3)

It is kown that at room temperature, hydrocarbons and ozone react to form compounds which decompose easily. For the purpose of air separation, the question arises whether at a temperature of 90° K. such a reaction will also start. Therefore, an examination was made to determine which fraction of hydrocarbons remains undecomposed if such hydrocarbon is brought in contact for a longer time with oxygen containing ozone.

In the first experiment (Table 3) 50 ml. gaseous oxygen with 2% ozone were added in glass bulb cooled to 90° K., to 50 ml. liquefied propylene. After 2 hr. a great deal of the original hydrocarbon was found again.

In the next experiment 20 ml. solid butylene were floated in 2 ml. liquid oxygen and 1 liter gaseous oxygen with 2% O_3 was bubbled through this mixture. After 18 hr., 74% butylene were found unreacted. Ozonides were not isolated.

These two experiments have shown that ozone does react with solid or liquid unsaturated hydrocarbons even at 90° K.

Thereupon tests with various ozone concentrations were carried out to determine the concentration of ozone in the liquid oxygen that raises the velocity of reaction up to explosion or self-ignition. For each test, 10-ml. gaseous hydrocarbons were condensed on the bottom of a test tube cooled to 90° K., and subsequently, liquid oxygen with known ozone content was added dropwise. Then either an explosion followed or not. The results are shown in Figure 1—3. The concentrations of ozone which release explosions are rather different for the various hydrocarbons all higher than 800 p.p.m., even higher than 5% with acetylene. Propylene explodes in liquid oxygen with 8000 p. p. m. ozone, but it does not explode at 800 p. p. m. The explosion of butylene or ethylene is not caused by 800 p. p. m. ozone. The behavior of acetylene is remarkable. Gaseous oxygen with 2% ozone was bubbled through a mixture of 20-ml. liquid oxygen and 5-ml. floating solid acetylene until the liquid had 5% ozone. No reaction was observed. Only when the liquid oxygen was evaporated did a violent detonation occur. The volume just before detonation had been reduced to about one fifth, and at the moment of detonation the concentration of ozone is assumed to have been about 25%.

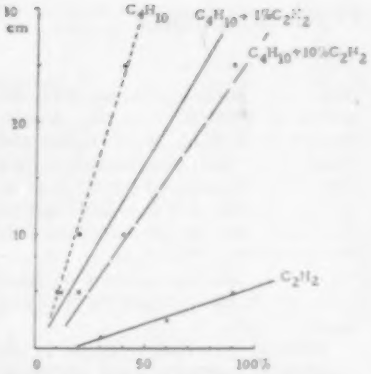

Figure 6. Explosion probability of different mixtures of butylene with acetylene in liquid oxygen.

Mixtures of hydrocarbons with NO_2 and ozone

The concentration of ozone causing an explosion of hydrocarbons in liquid oxygen is in some cases lowered by the presence of NO_2. In each of these experiments 10-ml. hydrocarbons were condensed in test tubes, the 5-ml. NO_2, and finally the liquid oxygen with ozone were added (tests marked in Figure 1 with double circles or crosses). Ozone (800 p. p. m.) which was not sufficient to effect self-ignition of pure ethylene, initiates an explosion of the ethylene in the presence of NO_2. The lower ozone concentration igniting a mixture butylene-NO_2 lies between 200 p. p. m. and 400 p. p. m. of ozone in the liquid oxygen, compared to 800 p. p. m. ozone for pure butylene. It was interesting to examine how mixtures of C_4H_8 and NO_2, which react at 400 p. p. m. of O_3, behave when mixed with acetylene, which is less able to react with O_2, with no other compound present.

At 90° K. 5-ml. C_2H_2 and 5 ml. C_4H_8 were condensed, 5-ml. NO_2 added, and finally nearly 1 g. liquid oxygen with ozone was dropped in the mixture. Figure 2 shows the result. In each of three tests no explosion occurred at 4000 p. p. m. O_3, i. e., more than tenfold the ozone limit for C_4H_8 + NO_2; however, in

continued

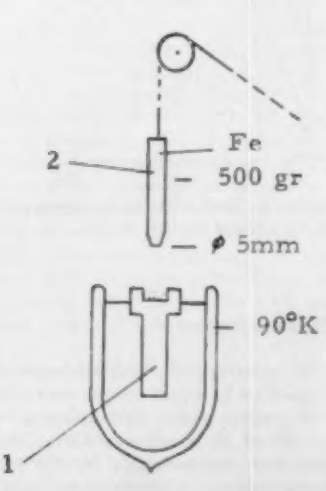

Figure 4. Impact tester.

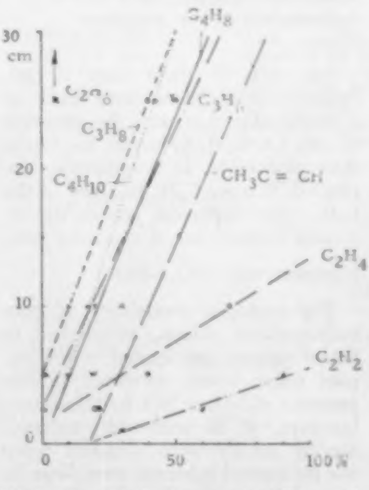

Figure 5. Explosion probability of pure hydrocarbons in liquid oxygen.

Hydrocarbons

continued

each case flame spreading was observed at 8000 p. p. m. O_3. A mixture of 9-ml. C_2H_2, 1-ml. C_4H_8, and 5-ml. NO_2 did not explode when liquid oxygen containing 8000 p. p. m. O_3 was poured in. It is evident and remarkable that in these experiments the reactivity of the C_4H_8 — NO_2 — O_2 — O_3 mixtures proved to have been noticeably reduced by the presence of C_2H_2.

Without immediate relation to air-separation purposes, some additional tests were carried out at room temperature, adding gaseous oxygen containing ozone to gaseous hydrocarbons, and it was surprising to see that C_2H_2 under these circumstances is the most reactive of all hydrocarbons, whereas solid C_2H_2 floating in liquid oxygen had proven to be rather insensitive towards ozone. Figure 3 shows that 0.2% of ozone in gaseous oxygen causes an explosion when added to gaseous acetylene. Ethylene is ignited by oxygen with 2% O_3 and for C_3H_6 or C_4H_8, still higher amounts of O_3 are needed.

Compared to the quantities of hydrocarbons used, the quantities of nitric oxides or concentrations of ozone in gaseous or liquid oxygen used in the experiments on self-ignition were much greater than ever will be encountered in the actual separation of air.

Effects in the experiments reported here can be used to judge only relative tendencies of events in the actual air separation but not the absolute magnitude.

Explosion test in the impact tester. (Figures 4-11)

Two-phase systems of mixtures of solid or liquid hydrocarbons with liquid oxygen detonate if the explosion is set off by a sufficiently hard mechanical impact. The explosion probability of hydrocarbon-liquid oxygen mixtures under such conditions was tested in an impact tester. In these tests the explosions could be set off by energies of different magnitude, energies being proportional to the height of the weight drops.

Tests were carried out with:

1. Pure hydrocarbons suspended in liquid oxygen.
2. Various mixtures in liquid oxygen (hydrocarbons with H_2O, CO_2, NO_2, NO, O_3).

Some glass powder was sprinkled on the cup, 1, of the impact tester* (Figure 4). The cup was then cooled down to 90° K., 10 cc. gaseous hydrocarbon were condensed, about 0.6 ml. of liquid oxygen was added, and finally the explosion was set off by dropping the weight, 2, (500 g). The explosion is identified by the sound. If neither the first nor the second impact sets off an explosion, the sample is discarded and the test is repeated with a new sample.

In Figures 5 to 11 the height of fall of the weight is shown as ordinate, the explosion probability as abscissa. The explosion probability is ratio of the number of explosions to the number of impacts carried out (in most cases 10). On one sample not more than two impacts were carried out.

* Developed at Linde laboratories in 1932.

Results

Pure hydrocarbons liquid oxygen (Figure 5)

The explosion probability of each hydrocarbon increases with increasing impact (height of fall of the weight). Hydrocarbons with the same C-number are more explosive the more unsaturated they are. Examples: ethane → ethylene → acetylene or propane → propylene → methylacetylene. C_2H_2 has the highest sensitivity to mechanical impact in such two-phase systems, followed by C_2H_4 → C_3H_6; C_4H_8 → C_3H_8; C_4H_{10}. C_2H_6 is comparatively insensitive. Acetylene remains the number one enemy.

It would be interesting to measure the velocity of propagation of the explosion, of the pressure wave, for instance, to determine whether the sequence of the various hydrocarbons then obtained is identical with the sequence found in the tests just described (Figure 5).

Admixture of C_2H_2 to a higher hydrocarbon raises sensitivity (Figure 6)

For each of these tests 10 ml. hydrocarbon-acetylene were used. It is remarkable that with the presence of only 1% C_2H_2 in butane the explosion probability is considerably increased. If more C_2H_2 is mixed to the C_4H_{10}, the explosion probability increases further, but at a smaller rate.

Hydrocarbons—NO_2—NO

The explosion probability of pure hydrocarbons which, suspended in liquid oxygen, are ignited in the impact tester is not increased by the presence of NO_2 or NO. In some cases, however, it is somewhat reduced. Similar results were obtained when the condensed mixtures were kept for some hours under liquid oxygen before the impact was given.

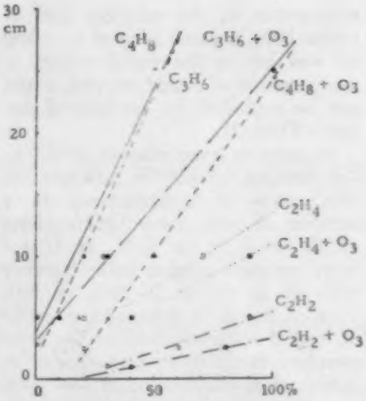

Figure 7. Increase of explosion probability of pure hydrocarbons caused by 100 p.p.m. ozone in liquid oxygen.

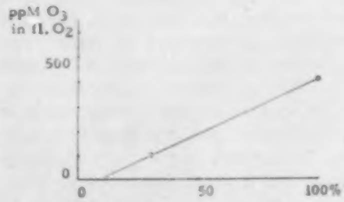

Figure 8. Dependence of explosion probability on content of ozone in liquid oxygen. Tests with a hydrocarbon mixture (90% C_4H_8 10% C_2H_2) in presence of NO_2, the fall height of the 500-g. weight being 1 cm.

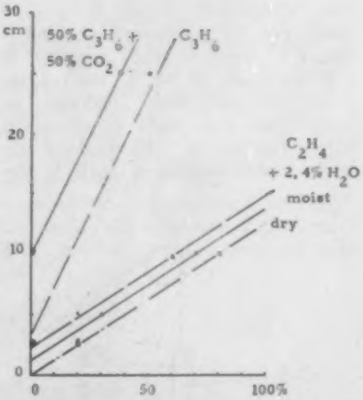

Figure 9. Reduction of explosion probability caused by H_2O or CO_2.

Hydrocarbons—ozone

If unsaturated hydrocarbons are suspended in liquid oxygen containing 100 p.p.m. ozone, the explosion can be set off by smaller excitation energies than are necessary for the same hydrocarbon in ozone-free oxygen (Figure 7).

In the next step the sensitivity to impact of one of the mixtures described here was tested, i.e., C_4H_8, which tends to self-ignition in the presence of ozone if NO_2 is added. The tests were run with ozone concentrations as variables, the height of fall being constant. Figure 8 shows the result. Five ml. NO_2 were added to 10 ml. condensed hydrocarbon mixture (90% C_2H_2, 10% C_4H_8). Furthermore, liquid oxygen with 100 and 400 p.p.m. O_3 was added. In each case the height of fall of the weight was 1 cm. According to Figure 7, pure C_2H_2 in liquid oxygen with 100 p.p.m. O_3 needs a 3.5 cm. height of fall of the drop weight for 100% explosion probability. The mixture used here, 60% C_2H_2, 7% C_4H_8, and 33% NO_2 does explode with 100% probability with only 1-cm. fall height if the concentration of the ozone is 400 p.p.m. Without mechanical impact, the ozone concentrations in liquid oxygen must be increased to more than 8,000 p.p.m. to effect the explosion by self-ignition in this mixture (see Figure 3). The nearer the O_3 concentration is to the concentration that leads to self-ignition, the easier all hydrocarbon-liquid oxygen-ozone mixtures can be brought to explosion by mechanical impact. The tests prove that an ozone content in the oxygen makes an explosion more likely. It should be kept in mind, however, that all concentrations of ozone used in these tests are considerably higher than any ozone concentrations that normally appear in air-separation plants.

Hydrocarbons H_2O—CO_2

Some tests are described using H_2O or CO_2 as a means of damping the sensitivity. Figure 9 shows the explosion probability of moist ethylene. The explosion probability is already considerably reduced by about 2 vol. % water vapor. The same condition obtains if 50% CO_2 are mixed with propylene. The damping effect of mixing various percentages of CO_2 to a given quantity of acetylene is shown in Figure 10. It is most remarkable that the explosion probability of C_2H_2 decreases enormously if more than 50% CO_2 are contained in the mixtures. But even smaller CO_2 contents reduce the hazard of the C_2H_2.

Hydrocarbons CO_2—CO_3

Figure 11 shows that in the system $C_2H_4 - CO_2 -$ liquid $O_2 + O_3$, carbon dioxide compensates the sensitizing effect of ozone and furthermore

continued

Table 1. Reactions between unsaturated hydrocarbons, oxides of nitrogen and oxygen at 20° C. and about 1 atm. abs., in daylight or dark.

TIME* DAYS	†	MIXTURES AT THE BEGINNING OF TESTS	RESIDUAL HYDROCARBONS AND REACTION PRODUCTS
0.7	L	8% NO, 16% C_2H_4, 75% O_2	yellow oil
4	D	100 ml. NO, 200 ml. C_2H_4, 768 ml. O_2	97 ml. C_2H_4 + yellow oil
4	L	100 ml. NO, 200 ml. C_2H_4, 873 ml. O_2	99 ml. C_2H_4 + yellow oil
8	L	29.6% NO, 31.8% O_2; 33.4% C_2H_4, 5.2% N_2	10.5% CO_2 + yellow oil
8	D	1,200 ml. NO, 1,220 ml. O_2, 1,280 ml. C_2H_4	542 ml. C_2H_4, 164 ml. CO_2 yellow oil & white crystals
2	L	150 ml. NO, 150 ml. C_3H_6, 300 ml. O_2	yellow oil ‡
7	L	1,190 ml. NO, 1,220 ml. C_3H_6, *ca.* 1,440 ml. O_2	81 ml. C_3H_6, yellow oil‡
7	L	1,190 ml. NO, 1,190 ml. C_4H_8, 2,380 ml. O_2	214 ml. C_4H_8, dark oil ‡

* Time given for reaction

† L = daylight, D = dark

‡ Soon after adding O_2 to the C_3— or C_4—NO mixture a yellowish fog arises and covers the vessel.

Table 2. Reactions between unsaturated hydrocarbons, oxides of nitrogen and oxygen at 90° K.

TEMP. °K.	DAYS*	MIXTURES AT THE BEGINNING OF TESTS	RESIDUAL COMPOUNDS AND REACTION PRODUCTS
90	5	30 ml. C_2H_4, 60 mg. NO_2(30 ml.), 30 ml. gaseous O_2	29.6 ml. C_2H_4; 60.2 mg. NO_2
90	7	50 ml. C_2H_4; 91.6 mg. NO_2 (50 ml.), 5 ml. liquid O_2	50 ml. C_2H_4; 94.6 mg. NO_2
90	7	30 ml. C_2H_4, *ca.* 30 ml. NO, *ca.* 5 ml. liquid O_2	30 ml. C_2H_4; 5.6 mg. NO, 33 ml. NO_2
90	5	50 ml. C_3H_6, 50 ml. NO, *ca.* 5 ml. liquid O_2	50.2 ml. C_3H_6
90	5	50 ml. C_3H_6, *ca.* 50 ml. NO_2, *ca.* 5 ml. liquid O_2	49.6 ml. C_3H_6
90	2	50 ml. C_4H_8, 50 ml. NO, *ca.* 5 ml. liquid O_2	50 ml. C_4H_8; 2.8 ml. NO
90	2	50 ml. C_4H_8, *ca.* 50 ml. NO_2, *ca.* 5 ml. liquid O_2	49.8 ml. C_4H_8
90	4	20 ml. C_2H_2, 20 ml. NO, *ca.* 5 ml. liquid O_2	20.5 ml. C_2H_2
90	4	20 ml. C_2H_2, 20 ml. NO_2, *ca.* 5 ml. liquid O_2	19.6 ml. C_2H_2
163	0.4	20 ml. liquid C_2H_2 + 400 ml. gaseous NO_2	little yellowish oil

* Time given for reaction

Table 3. Reactions between ozone and hydrocarbons at 90°K

TEMP. °K.	TIME *) HR.	MIXTURES AT THE BEGINNING OF TESTS	REFOUND SUBSTANCES
90	2	50 ml. C_2H_4, 49 ml. O_2, 1 ml. O_3 (all gaseous)	48.1 ml. C_2H_4
90	18	20 ml. C_2H_4, 16 ml. gaseous O_2, 2 ml. liquid O_3	14.8 ml. C_2H_4

*) time given for reaction

Table 4.

Hydrocarbon		C_2H_2	C_2H_4	C_3H_6	C_4H_8	C_3H_8	C_4H_6	C_4H_{10}
Solubility in liquid O_2, *T* 390°K.	p.p.m.	5.6	20 000	128 000	3 600	9 800	109	175
Vapor pressure, kg. · 10^{-6} at 100°K.	/sq. cm.	5	550	110	3.6	1.6	0.05	0.017
Concentration in p.p.m. air of 5.6 kg/sq. cm. and 100°K.		0.9	100	20	0.64	0.28	$0.9.10^{-2}$	$0.3.10^{-2}$

Hydrocarbons

continued

reduces the explosion probability, thus playing the role of a welcome protector. The protective effect of CO_2 and H_2O, as observed in such impact tests, is a reality under normal operating conditions since the concentrations of CO_2 and H_2O in liquid oxygen are often higher than that of hydrocarbons.

Solutions and explosion tests with primer cap

Methods employed in the determination of solubility:

a. Observing the appearance of a second phase when feeding a measured quantity of a hydrocarbon to liquid oxygen.
b. Condensing a gaseous mixture of oxygen and hydrocarbons at a pressure higher than the critical pressure; cooling it down to the temperature at which the solubility shall be measured; filtering off the separated solid hydrocarbon-phase, reevaporating the saturated solution under a pressure higher than the critical pressure. In the use of this method, it is a condition that, at constant temperature, the solubility will not be considerably influenced by the pressure acting on the liquid.
c. For hydrocarbons which, at 90° K. form a separate liquid phase in the liquid oxygen: condensing a mixture of oxygen and hydrocarbons until a two-phase system is formed; separating and analyzing the phase rich in oxygen.

Table 4 shows the solubility of hydrocarbons in liquid oxygen at 90° K. The solubility decreases for both saturated and unsaturated hydrocarbons as the number of C-atoms increases. Moreover, it also decreases with the number of double linkages, the number of C-atoms being constant. With the exception of acetylene, hydrocarbons may be said to be fairly soluble. If several hydrocarbons are dissolved simultaneously in liquid oxygen, then the solubility is influenced to a certain degree; for instance, the solubility of the acetylene is increased by the presence of C_3H_6. However, the influence is within the range of accuracy error of the solubility measurement.

In order to examine the explosion limits of hydrocarbons in liquid oxygen, 0.5 to 10 liters of liquid oxygen containing various quantities of hydrocarbons in unsaturated solutions were filled into cold copper cylinders of corresponding size. Then the explosions were set off by means of electrically initiated primer caps. The copper cylinders were deformed or ruptured as a result. By way of evaluation the volumes of the cylinders were compared with those of cylinders in which primer caps alone had been set off.

Unsaturated solutions with less than 1 mole % of CH_4 or C_2H_4 or C_2H_6 cannot be brought to explode with primer caps. Rich solutions, especially stoichiometric mixtures, react with velocities equaling explosion. Acetylene, the C_3 and C_4, and higher hydrocarbons cannot be made to explode as long as their concentrations do not exceed the limit of solubility. However, all two-phase systems liquid-solid or liquid-liquid bring about violent explosions. No less dangerous of course, are accumulations of solid or liquid hydrocarbons moistened with unsaturated liquid oxygen.

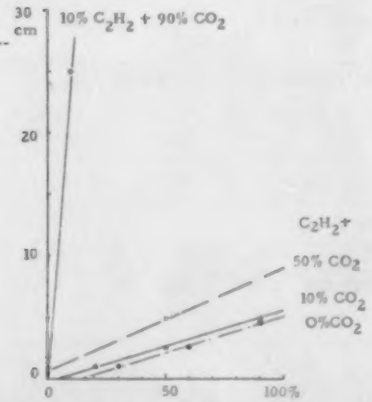

Figure 10. Reduction of explosion probability of C_2H_2 caused by CO_2.

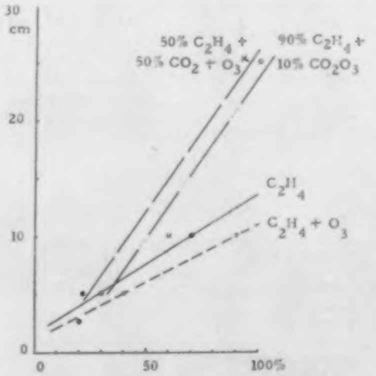

Figure 11. Reduction of explosion probability of C_2H_4 caused by CO_2 in liquid oxygen containing 200 p.p.m. ozone.

Evaluation of admissible hydrocarbon contents in air

The concentration of any hydrocarbon and other impurity admissible in the feed of an air-separation plant cannot be determined by considering a single property of a hydrocarbon only, but rather on the basis of all its relevant physical and chemical properties, including the cycle and design of the plant. Vapor pressures, partial pressures, adsorption behavior, solubility in liquid oxygen, fugacity from the solution, and state of aggregation are the physical bases; the explosion sensitivity, the reactivity with nitric oxides and ozone, and damping effect of H_2O or CO_2 are the chemical bases on which a judgment on the passage of the hydrocarbons through the air separator will be formed and which, finally after a consideration of the peculiarities of the separation procedure, permit a determination of the admissible content in the air.

Features of the separating procedure which have to be considered are, for instance, whether continuously operating tubular exchangers or self-cleaning regenerators or reversing exchangers are used; the use of adsorbers in the stream of the gaseous air to be cooled, or in the stream of the rich liquid between the lower and the upper rectifications column; whether the oxygen product is withdrawn as gas or liquid from the main condenser, and the evaporation of this liquid in an auxiliary vaporizer, if any.

The method of evaluation may be illustrated on the example of an air-separation plant of the Linde Fränkl system. This system works with regenerators. In the regenerators, hydrocarbons are condensed and reevaporated just like carbon dioxide.

Table 4 shows the vapor pressures and concentrations of the hydrocarbons at the cold end of a nitrogen regenerator for a total pressure of the air of 5.6 kg./sq. cm. and a temperature of 100° K. Higher concentrations are retained from the rectification columns by condensation and reevaporation in the regenerator, lower concentrations flow to the rectification column.

Without an adsorber between the high- and low-pressure columns any nonfugitive hydrocarbon does reach the 5.25 fold of the figures of line 3 in the liquid oxygen of the main condenser, and this concentration increases 200-fold after the liquid oxygen of the main condenser is vaporized in the auxiliary vaporizer except for a residue of 0.5%. Thus, the C_4

and C_4 hydrocarbons would appear in the remaining liquid with concentrations of 9.5 p.p.m. C_4H_8; 3 p.p.m. C_4H_{10}; 630 p.p.m. C_2H_6, and 300 p.p.m. C_3H_8. All these solutions are far away from the solubility-limits of line 1 and can be regarded as safe. As a conclusion it might appear permissible that any accidental concentration of C_2-C_4 hydrocarbons is admissible in the entering air. Considerations of safety in the regenerator, however, prevail against such reasoning. However, this point will be treated in a supplementary paper.

Another way of determining admissible concentrations of hydrocarbons can be demonstrated by the example of the C_2-hydrocarbons. One stipulates as a general safety rule that at no place in the air separator should it be possible to form solutions that contain more than one third of the solubility limit i.e., 6,600 p.pm. C_2H_4 or more than 1 vol. % C_2H_6. Working back from the 0.5% of unevaporated liquid downstream of the auxiliary condenser, where this condition should be met, the liquid oxygen in the main condenser will contain 33 p.p.m. C_2H_4 and 50 p.p.m. C_2H_6 (0.15 and 0.04 % saturation, therefore, judged safe.). If the efficiency of the acetylene-adsorber is 97% for acetylene and 30% for C_2H_4 and C_2H_6 respectively, the air entering the regenerators may then contain 9 p.p.m. C_2H_4 and 13.5 p.p.m. C_2H_6. Experimental verification of these figures is still outstanding.

Occasionally it may be desirable that a plant can be run on higher concentrations of ethylene or ethane. Then, in the auxiliary vaporizer a greater part of the oxygen to be produced, i.e., 5%, will be left unevaporated and will be pumped back to the main condenser after passing an adsorber, which retains the hydrocarbons. Only such vaporizers are suitable for this purpose in which the liquid and its vapors flow in the same direction.

To determine the admissible acetylene-content at the air inlet, one has to remember that acetylene has a high fugacity out of its solutions in liquid oxygen. Starting with an allowable content of 3 p.p.m. C_2H_2 at the end of the auxiliary vaporizer, the calculations show 0.1 p.p.m. C_2H_2 in the main condenser and with a 97% efficiency of the acetylene-adsorber, the admissible acetylene content of the air to 0.5 p.p.m. C_2H_2.

Attention is called to the fact that the foregoing determination refers only to normal Linde-Fränkl plants, with their individual safety precautions, and that other systems of air separations require somewhat different considerations. This is true for tonnage-oxygen plants as well as for plants with tube-and-shell heat exchangers. In the latter type of plant almost complete protection against high acetylene concentrations in the air is offered by adsorbers at the dew-point temperature of the carbon dioxide before expansion of the air. Likewise layers of gel in a regenerator offer protection to a plant using regenerators.

ACKNOWLEDGMENT

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development of a Refinery simulation program

How one particular simulation program, written for a medium-sized computer, accomplishes a high degree of automatic balancing and decision making while recognizing a wide range of variables.

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The purpose of this article is threefold: *first*, to define the basic problem facing today's refinery economist; *second*, to discuss plant simulation by an electronic computer as an aid to the refinery economist and to present the requirements and properties of a satisfactory plant simulation procedure; and *third*, to illustrate these requirements by specific examples taken from an actual refinery simulation program. The major part of this paper has been devoted to the third objective. An attempt has been made to give a concrete picture both of the degree of perfection which can reasonably be expected from such a program, and of the magnitude of the time and effort which must go into its preparation and use.

The complexity of modern petroleum refining greatly limits the ability of a refinery economist to evaluate new manufacturing schemes. Rigorous calculation of every effect and interaction with only a desk calculator as a tool is impossible within

continued

Refinery simulation program
continued

the time usually allotted for obtaining answers. The value of the results obtained for a given problem is highly dependent on the skill of the individual economist in differentiating between major effects, which must be evaluated rigorously, and minor ones, which may be ignored. Although the technique of plant simulation on electronic computers does not wholly alleviate this problem, it does make it possible to expand greatly the range of actions and interactions which can be considered in routine evaluations, thereby minimizing the chance that an important effect may be ignored.

Optimum utilization of physical facilities is becoming an absolute necessity if a company is to hold its own in the increasingly competitive field of petroleum refining. The refinery economist, when facing this problem of optimization, is confronted with a tremendous array of options and complex interlocking restrictions. Furthermore, the optimum is dynamic, rather than static. In addition to the fluctuating price of crude oils, the refiner is faced with both seasonal and unpredictable variations in price, demand, and specifications of his major products. The expanding field of petrochemicals has served to add another dimension to this already complicated picture.

The solution of a refinery economic problem demands exacting calculation of the over-all effects of incremental changes in plant operations. The size of the problem, and the number of factors which must be considered prevent the rapid manual solution of an average problem in complete form. Short cuts must be taken, and many secondary effects and interactions ignored. The validity of the answers is highly dependent on the skill of the economist in differentiating between major and minor effects and concentrating the available time and effort on the major ones.

In the past, this problem has not proved insurmountable. However, advances in refinery technology, higher product quality, and ventures into more diversified manufacturing fields have made this job of simplifying the problem difficult. Partial solutions to an economic problem, considering effects on only one or two processing units, are frequently in error with respect to magnitude, and can even be in error with respect to direction.

The most common method of attacking a problem in refinery economics involves the calculation, in great detail, of a base case. Alternate cases are then worked out and compared with the base case (usually by subtracting all similar items in one case from the other, both barrelwise and dollarwise). One then ends up with a table of differences, in which many minor errors in data or logic have cancelled each other, and there remains only the best estimate of the effects of the change. The preparation of these cases is a long and tedious job and may require many man-days. Complete material balances must be closed around every unit in the plant. Yield correlations must be evaluated for the various units. Extreme care is necessary in every step of the operation, since the final step will be the subtraction of two sets of large numbers to yield a small difference to which costs will be applied, on which final decision will be based.

Requirements of a plant simulation program

An integrated system of computer techniques for studying refinery economics contains several different tools. These can be conveniently broken down into statistical techniques, optimization programs, and case study simulation systems. The first two tools, typified by multiple regression, and linear programming are thoroughly discussed in the literature. The last item, case study simulation, is less familiar in that few complete systems have been described.

The computer represents a tool which can generate base and alternate economic cases. It does this with a speed, accuracy, and thoroughness which cannot be approached in hand calculations. In order to perform this case-generating task efficiently, the simulation program must meet certain fundamental requirements.

First, it must be an accurate and complete mathematical and logical model of the plant. The material balances around each unit must reflect capacity limitations, feed stock quality, and appropriate relations between processing conditions and product mix. The choices and logical decisions made by the computer must be at least as good as those that would be made by the skilled economist.

The need for proper recognition of incremental effects is not limited to strictly quantitative aspects, such as unit yield structures and product inspections. There may also be qualitative changes in a refinery operation as the result of an incremental change in

CAT LIGHT ENDS CONCENTRATION

	Gas and Loss	C3 Unsats	Propane	I-C4	C4 Unsats	N-C4	C5 Plus Gasoline	Totals
Cat Light Ends	1,195	805	559	676	804	141		4,180
Plant 1 Gas	560	111	264	107	107	344	286	1,119
Plat Pref Ohd Gas	205		51	31		65	162	514
Stabilizer Ohd Gas	111		27	17		35	87	277
Totals	2,071	916	901	831	911	585	535	6,750
Gas and Loss to Fuel	2,071	229	225	42				2,567
Alkylation Unit		687	676	789	911	585		3,648
Cat Gasoline								
Totals	2,071	916	901	831	911	585	535	6,750
Gas Composition	B/CD	Vol. %						
H2s	166	6.47						
Hydrogen	238	9.27						
Methane	894	34.83						
Ethylene	342	13.32						
Ethane	431	16.79						
Propylene	229	8.92						
Propane	225	8.77						
C4 and Heavy.	42	1.63						
Total	2,567	100.00						

FIGURE 1. SAMPLE OUTPUT PAGE

. . . it may appear unnecessary to emphasize the importance of a thorough analysis of the complete problem before beginning actual work, but in any type of computer work it cannot be repeated too often.

charge or product rates and qualities. A new stock may be a preferred charge for a given unit, rather than another material appearing in the base case. The base case material, in the proper amount, must be backed out of the unit in question and put to an alternate disposition. This alternate disposition may in turn result in certain other limitations being exceeded, and cause a complete rescheduling of a major portion of the refinery. Effects of this type are often determining factors in an economic evaluation, and if they are not handled properly, the value of the program is severely limited.

Finally, the program must not be rigidly tied to the immediate configuration of the refinery. The main purpose of this tool is to serve as an aid in evaluating the effects of change. This change may be confined to operating data, such as charge rates, yield structures, product requirements, unit downtime schedules, and so on. On the other hand, it is often desirable to investigate the effect of a change in the refinery itself, or in the basic techniques of scheduling an operation. If the simulation program must be rewritten every time an alternative of this sort is to be investigated, it may well prove to be a liability, rather than an asset to the economist. It is perhaps obvious that this feature of easily handling gross changes in scheduling is the most difficult and elusive single requirement for a simulation program to meet.

The equipment in question is a medium-sized (50,000 to 100,000 bbl./day crude charge) modern refinery, producing a complete slate of fuel products and solvents. The program was prepared for an IBM Type 650 computer with no auxiliary features other than alphabetic input and output. This computer has an internal memory of 2000 ten digit numbers. Input and output is through punched cards exclusively, with reading and punching speeds of 200 and 100 cards/min. respectively.

Development of basic tools and procedures

As a result of the analysis of the abilities and limitations of the computer it was decided to prepare a specially designed "interpretive" programming system. This is a procedure in which instructions to the computer are written, not in the basic language which the computer is wired to understand, but in a shorthand "pseudo code," with each instruction carrying information equivalent to several machine language instructions. The computer is then provided with an "interpreter," a set of instructions written in basic machine language which enables it to interpret and properly execute these pseudo codes.

The penalties for adopting this procedure are twofold. First, the operational speed of the computer is decreased by the necessity for interpreting each pseudo code before the actual operation can be performed. Second, a portion of the computer's memory (20%, in this particular case) must be given up to the routine for performing this interpretation. The benefits are also twofold, and more than offset these penalties. First, the ease of programming is greatly increased. In designing his system of pseudo codes, the programmer has the option of selecting commands corresponding to the basic steps in the manual solution of the problem. For example, he may include a single command which will cause the computer to inspect a table of argument and function values, and interpolate in the function table according to a specified argument value. The second, and more important advantage comes from the shorthand nature of the pseudo codes. The statement of any phase of the problem requires less memory in pseudo codes than would be required in the use of machine language commands. This more than offsets the amount of memory allocated to the interpreter itself, and results in effectively stretching memory several fold.

It may appear unnecessary to emphasize the importance of a thorough analysis of the complete problem before beginning actual work. In any type of computer work, however, it cannot be overemphasized or repeated too often. In this particular case, final results would have fallen far short of those actually obtained if the decision to use a specialized programming technique had not been made early in the project. This decision, in turn, resulted directly from a thorough initial study of the over-all requirements and limitations of the problem and computer.

Once the basic programming system had been designed, attention was turned to the method of output preparation. it was decided that in order to maintain maximum utility, the output should be in the form of a completely self-contained report, suitable for printing onto reproduction masters, which in turn could be used to prepare a multipage report for distribution directly to management.

Since the computer did not have an attached printing unit, auxiliary punched-card equipment was used for the preparation of this report. Specifically, the system which was adopted is one in which answer cards with an identifying code are punched by the computer as results are developed. These are then combined on auxiliary equipment with a set of permanent description cards, containing alphabetic information and control punches dictating the arrangement and format of numbers to be transcribed from the machine-punched answer cards onto the printed page. The combined deck is then fed to a printer. The result is a final page similar to that shown in Figure 1, produced by completely routine card-handling procedures.

The arrangement of information on this page is of interest since it is typical of a standard layout which is established for all the output information. In this format, a single page is assigned to each unit in the refinery. The columns on the page correspond to the basic streams produced on that unit. The top half of the page is devoted to a listing of the charge stocks to the unit, by rows, with the product breakdown from each charge shown in the appropriate column. This information is then totaled, both horizontally by charges and vertically by products. The totals line is followed by a section devoted to product dispositions, in which a line is allocated to each product destination. Finally, these dispositions are totaled horizontally and vertically to provide a visual check with the charges. A rigid rule was established that any number appearing as a charge must also appear somewhere else in the scheme as a disposition, and vice versa, simplifying the job of manually tracing the flow through the set of printed pages. Finally, provision was made for the

continued

Refinery simulation program

continued

printing of supplemental information and footnotes after the totals line of the disposition section.

Description of the program

A general outline of the program is given here with certain areas discussed in detail. The purpose of this is to give a concept of the degree of accuracy and completeness with which certain common refinery scheduling problems involving several plants and products are incorporated into a typical plant simulation program.

The refinery in question processes a great variety of crudes every month, and the crudes processed may vary from month to month. One of the principal anticipated uses of the refinery simulation program was for the evaluation of potential crude purchases. For this reason, emphasis was placed upon the crude distillation step in the preparation of the final program. Each crude charged to the refinery is defined by a group of approximately a dozen cards, one of these cards specifying the volume and price of the crude in question to be charged in the current study. The rest of the cards constitute a permanent library file on that particular crude, its physical properties, etc., transcribed directly from the original crude assay report. These cards are processed by the computer, and the yields and composite inspections of the various streams produced from the crude distillation units are calculated.

It is at this point that the problem of preferential allocation of stocks first appears. The allocation of gasoline boiling range stocks is a typical example of this problem.

Gasoline allocation

As shown in Figure 2, there are five primary dispositions for material in this boiling range. These include 1) Platformer charge, 2) Platformer charge to inventory, 3) straight-run motor gasoline, 4) thermal reforming unit charge, and 5) jet fuel. The volumes required by each of these consumers are determined in several different ways. The Platformer charge is calculated as a function of gasoline quality and must simultaneously satisfy certain solvents requirements as well as limitations on three units. The Platformer charge to inventory and straight-run motor gasoline volumes are specified as data. The amount to be charged to the thermal coils is also specified as data, but the same amount may be subject to capacity limitations on the unit itself. Finally, any gasoline not diverted to one of the preceding four dispositions is rerun for jet fuel. The amount allocated to each of these dispositions is also limited by the availability of gasoline at the minimum acceptable quality level. Since the information necessary for determination of the Platformer charge volume cannot be developed until after the crude distillation phase is complete, it is impossible to allocate the various gasoline stocks as they are distilled. Instead, the problem is handled in the following fashion.

As each crude is distilled, its gasoline fraction is blended into one of three segregated pools, depending upon its aromatic and naphthene content. Highly naphthenic crudes are placed in pool No. 1, and constitute prime Platformer charge. Paraffinic crudes are allocated to pool No. 3, and are defined as being suitable only for thermal reforming or jet fuel. Intermediate stocks are placed in pool 2. As the five dispositions just referred to appear in sequence in the program, they are filled from these three pools. In each case, the computer will attempt first to fill the requirement from pool No. 1, moving to pool No. 2 or 3 if sufficient prime quality stock is not available. Figure 2 illustrates the combinations which are possible. The selection of three pools for segregation was not an arbitrary one, neither was it imposed by limitations of the computer nor the program. Instead, this degree of segregation was selected as being representative of the actual degree of segregation practiced in the refinery itself.

A final complicating factor in the gasoline picture is introduced by the fact that the endpoint of the gasoline cut charged to the Platformer prefractionator is varied to conform with a bottoms rate limitation on the prefractionator. To meet this situation, the computer first distills the gasoline to a standard cut point, and then, during the prefractionator section of the particular program, computes a correction factor to adjust the gasoline rate to its proper volume, making a corresponding adjustment in the adjacent kerosene stream.

Platformer charge selection

For every problem of product allocation, there exists a parallel one of feed-stock selection. This can be illustrated by considering the way in which the Platformer charge is determined. This program block immediately follows the crude distillation calculation. The reactor charge rate is specified as data to the program. The problem then reduces to one of selecting a prefractionator charge rate, prefractionator cut point, and prefractionator charge endpoint which will simultaneously satisfy several solvent requirements, the specified reactor charge rate, and a stream-day bottoms limitation on the prefractionator tower itself. The Platformer correlations must be evaluated in terms of the aromaticity, naphthene content, and endpoint of the reactor charge. The situation is further complicated by the fact that the average quality of the prefractionator charge is not known at this point. Instead, the computer has available to it only the volume and analysis of

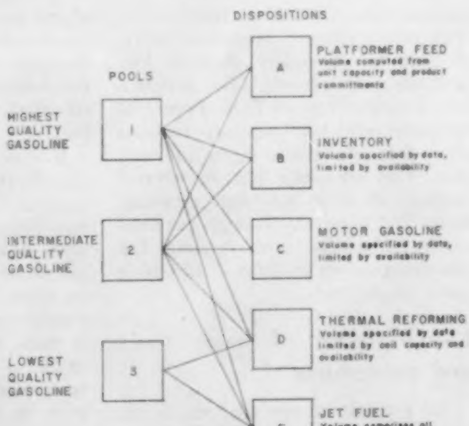

Figure 2. Straight-run gasoline allocation.

. . . the third major block of the simulation program includes the light ends systems and the processing sequence for the kerosenes, catfeed stocks, and residual fuels.

several pools of potential prefractionator charge of successively poorer quality. The calculation itself is a two-level trial-and-error reckoning. In actual practice, the entire operation, including evaluation of Platformer correlations and punching of prefractionator and Platformer material balances, consumes less than five minutes.

The Platformer and associated units concerned with the production of solvents constitute the second major block of programming (crude distillation was the first block.) This block also contains the "chemical fractionation unit."

Chemical fractionation unit

This unit consists of several distillation towers, and is used to rerun various streams produced in the refinery for the production of aromatic and aliphatic solvents and specialties. Within the period covered by any particular study, it may be desired to schedule as many as five or ten different operations on this unit.

The computer is provided with a library of all possible operations on the unit. Each operation is represented by a single card, specifying the charge stock to the operation, the dispositions of all the products, the yield structure, the stream-day charge rate, and an identifying operation number. This library will normally contain forty or fifty items, and may, in theory, contain several hundred. The economist fills out a "requirements" card for each operation he wishes to include in the particular plan under study, the cards specifying the operation number and either the desired volume of charge stock to be processed, or the required volume of any product to be produced from that operation. The computer loads the requirements cards, and then automatically searches the library to compile a complete file of information on each operation. The operations are processed in the same sequence in which the requirements cards were loaded into the computer. The charge rate for each operation is set to meet the charge or product rate requirements specified by the economist, subject to limitations in available charge stock or unit capacity. Provision is made for charging materials to and from inventory, for charging the products of other units, or for recycling the product of one chemical fractionation operation to a later, second pass operation on the same unit.

Bunker C blending

The third major block of the simulation program includes the light ends systems and the processing sequence for the kerosenes, catfeed stocks, and residual fuels. The Bunker C calculation illustrates several important points. Of particular interest in this section is the way in which downtime on the various units are handled.

Figure 3 shows the basic flow of the Bunker C components. In the normal flow, topping unit bottoms are charged to the vacuum unit, and vacuum tower bottoms to the thermal cracking unit, producing a pool of Bunker C base stock. At the same time, catalytic cracking feed from the topping unit, vacuum tower, and thermal cracking unit is charged to the catalytic cracking unit. Some products from catalytic cracking, plus cutter stock from inventory, if needed, are used to blend the Bunker C to viscosity specifications. The blending properties of the Bunker C base stocks are calculated as the end product of a series of correlations beginning with data on the crude itself, and including correlations around the vacuum unit and visbreaker (thermal cracking unit).

When the vacuum unit is shut down for general repair work, it is necessary to by-pass its feed directly to the thermal cracking unit, since no intermediate storage is provided for this material. To minimize the amount of material by-passed in this way, the refinery is usually scheduled such that crudes producing minimum bottoms yields are being run during that period when the vacuum unit is down. To reflect this operating flexibility, the economist is able to specify the stream-day rate at which topping unit bottoms are to be by-passed around the vacuum unit during downtimes. This material goes to the thermal cracking system with its properties unaltered from those calculated by the crude distillation program. The balance of the topping unit bottoms is processed through the vacuum unit, and the properties of the vacuum tower bottoms calculated by correlation. Simultaneous downtimes of the topping unit and vacuum unit can be represented by simply specifying a zero by-pass rate.

Planned maintenance minimizes the chances of a situation requiring simultaneous downtime of the vacuum unit and visbreaker, when the topping units are on stream, so no provision was made in the program for by-passing topping unit bottoms around the vacuum unit and visbreaker. On the other hand, two routes are supplied for by-passing vacuum unit

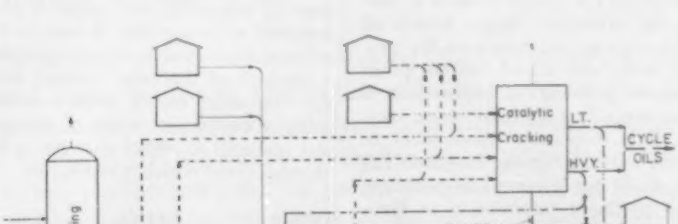

Figure 3. Bunker C blending.

continued

bottoms around the visbreaker. The first of these represents material by-passed during downtimes. Here, the economist specifies the properties of the material to be by-passed, reflecting actual flexibility possible in the plant operation. The volume and quality of the pool remaining is calculated, and its capacity requirements compared with the visbreaker capacity available *after* processing any by-passed topping unit bottoms. If the available capacity is insufficient to process all this material, a portion is by-passed at average quality. Finally, the Bunker C base stocks, representing some material processed through the topping unit and vacuum unit, some through the topping unit and vis unit, some through all three units, and some produced from other charges to the visbreaker unit are combined into a single pool for blending.

At the same time that the Bunker C base stock pool is being accumulated, a pool of potential catalytic cracking unit charges has also been prepared. The computer selectively picks enough material from this pool to fill the cat unit, by-passing materials to inventory or bringing in purchased catfeed stocks as needed. The cat cracking correlations are evaluated, and the volume of all catalytically cracked products is calculated. After diversion of specified amounts of heavy gas oil to No. 2 gas oil and thermal cracking, the slurry and remaining heavy gas oil streams are used to blend Bunker C fuel to viscosity specifications. At this point, several new possibilities present themselves. If the slurry and heavy gas oil are sufficient to bring the Bunker C pool onto specification, then any excess heavy gas oil will be automatically yielded to inventory. If they are insufficient, however, the economist may specify the maximum available volume of two purchased cutter stocks, in order of preference, and may also state whether he wishes light gas oil to be used as a cutter stock, if needed. The computer will dip into whatever stocks have been made available to it in this way, either blending all of the Bunker C to final specifications, or yielding any unblended material to inventory. A final recap shows the complete breakdown of the finished Bunker C pool, including gravities and sulfur contents on all stocks and on the finished blend.

With reference again to Figure 3, it is apparent that the preceding discussion has been limited to only a portion of the processing shown. It is, therefore, a simplified description. The main point of interest is that by carefully selecting the key variables to be specified by the economist, this complex system with its feed-back loops can be automatically balanced according to an economic policy defined by the data.

Final balances

For every unit in the refinery, calculations are performed to the nearest one-hundredth barrel, and then rounded to even barrels. Care is taken to insure that all units balance exactly, and that there are no discrepancies between numbers carried forward from one unit to the next. The fourth and final block of the program collects all of the net charges to, and products from, the refinery into a single charge and product recap report. At this point, prices and values are assigned to all stocks, and a gross refinery realization is calculated. Materials for which a series of contract commitments exist are handled by a section of the program which accepts statements of the contract volumes and prices in order of preference for filling the commitments. If insufficient material has been produced to meet all commitments, cards are punched which print as a separate "contract shortage" report, identifying the contractor and showing the shortage, the unit price, and the total value.

Method of use

The type of simulation program discussed here may be used in a variety of ways. In the preparation of a base case, the economist simply inserts all of the appropriate data into the program deck, and allows the computer to run the problem out to completion. When evaluating alternate cases, however, it is frequently unnecessary to run the entire program. Provision has been made for a complete punchout of all pertinent information at three points in the program: immediately after the crude distillation, immediately after the solvents operations, and before the final recap calculation. In this way, if a series of studies is to determine the effect of varying downtime policies on the vacuum unit and visbreaker, it is only necessary to reload the "punchout after solvents" to restore the computer to the condition in which it would be if the program had been run up to this point. Provision has also been made for reloading the punchout after the crude distillation step and processing incremental crudes in and out of the refinery. This is an especially important time-saving feature, since the crude distillation step represents approximately half the total running time of the program. The remaining 50% is divided approximately 20:20:10 among the chemical and solvents block, the cat unit and heavy fuels block, and the final recap respectively. The total running time for a typical problem, involving the processing of twenty-five to thirty crudes, is approximately one hour.

Magnitude of project

Although it is impossible to determine the precise amount of effort expended on this program, the estimates in the following paragraphs are presented to give the reader a feeling for the orders of magnitude involved.

Approximately one and one-half to two man years of technical work went into the development of this program. Of this total, approximately one half was spent by persons with experience and knowledge of both refining and computing, while the balance was by persons with essentially no experience in computing, and was devoted to organizing data and correlations, and in precise definition of the problem. A total of 50 to 100 hr. of computer time was used in checking out and debugging the complete program.

The finished program contains approximately 5000 interpretive instructions, equivalent to perhaps 20,000 to 25,000 machine-language instructions. As stated previously, it requires approximately one hour of total running time for the solution of a single case. Since a project of this sort has neither a sharp beginning nor a well-refined ending, the best that can be done in estimating the calendar time required is to say that it was in the order of six to twelve calendar months. A program of this type is never actually complete, but is always undergoing a continuous series of changes and revisions to reflect changes in the physical plant which it represents.

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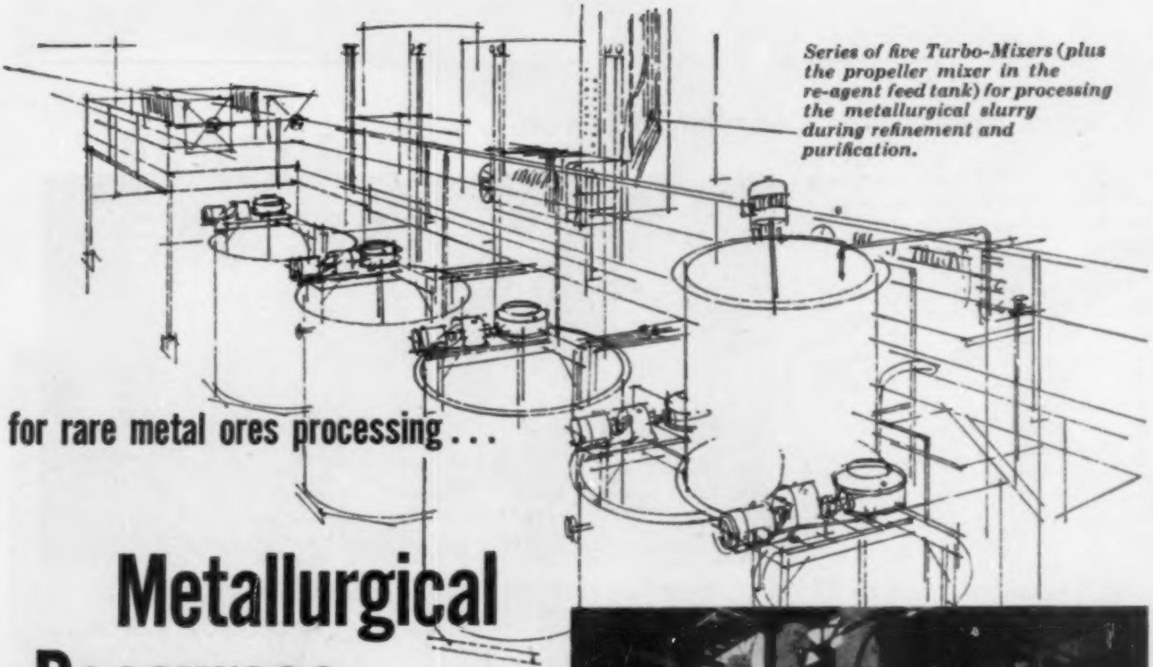
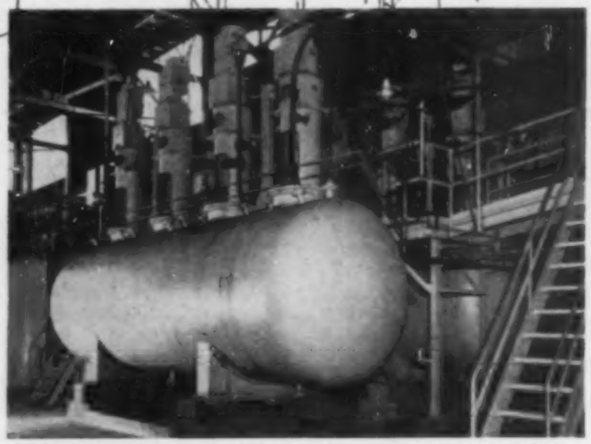
Presented at A.I.Ch.E. meeting, Chicago, Ill.



Series of five Turbo-Mixers (plus the propeller mixer in the re-agent feed tank) for processing the metallurgical slurry during refinement and purification.

for rare metal ores processing . . .

Metallurgical Resources chooses TURBO-MIXERS



Four-compartment autoclaves for pressure leaching of ore. Each mixer consists of a mixing and aeration assembly to accomplish the contacting of the liquid-solid-gaseous phase system.

There is no easy way to extract rare metals from their ores. Processing plants, such as that of Metallurgical Resources, Inc. of Newburgh, New York, call for skillful design and dependable processing equipment. To help put this new plant "on stream", Turbo-Mixer custom made all of the equipment required.

Turbo's 45 years of experience in design . . . Turbo's record of dependability . . . and Turbo's single-source responsibility make the difference. If you are in the process of selecting or specifying mixing equipment, call on Turbo. You'll find . . . *it pays to plan with General American.*

FOR DETAILED INFORMATION AND USEFUL DESIGN DATA, SEND FOR THE FOLLOWING BULLETINS:

Please send me the following Turbo-Mixer Bulletin (s):

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Sales offices: 380 Madison Avenue, New York 17, New York • General Offices: 135 South LaSalle Street, Chicago 90, Illinois • Offices in all principal cities

Commercial-scale direct reduction of iron ore

New process claimed to eliminate coal and limestone as necessary raw material basis for steel industry.

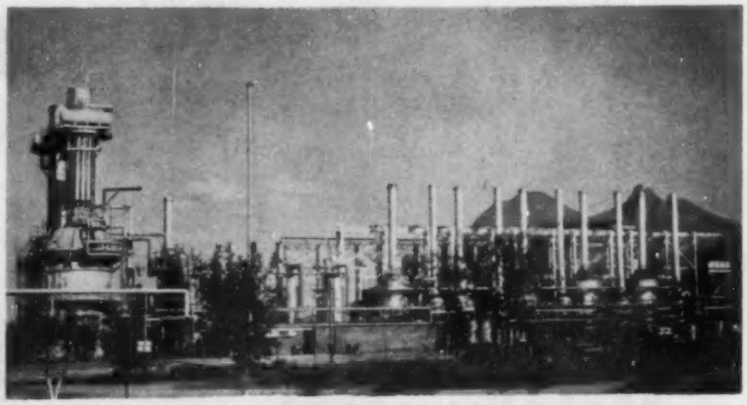
A 200 ton per day plant for production of sponge iron from iron ore by direct reduction with natural gas has been in successful operation in Mexico for several months, and a contract has been awarded for the building of a second plant with a 500 ton capacity. Producer is Fierro Esponja of Monterrey, Mexico; the process was developed with the engineering assistance of M. W. Kellogg of New York.

It is claimed, that, since the new process eliminates the need for coal and limestone, major raw materials in the conventional blast furnace, the process will be applicable wherever supplies of coal or limestone are limited but either natural gas or petroleum is available. Relatively small capital investment requirements are said to make possible much smaller scale installations than are now possible with conventional steel plants.

The proposed new 500 ton unit for Monterrey, to be engineered by Kellogg, will stress thermal efficiency, will embody design features developed from data on the operation of the 200 ton unit.

The reducing gas, produced in five high-pressure steam reforming furnaces will contain 85% hydrogen and carbon monoxide, and will be sulfur-free. Actual reduction of the ore will be performed in four reactors, each holding approximately 105 tons of ore. On discharge from the reactors, the sponge iron can either be sent directly to electric furnaces, or can be stored for later shipment to steel plants. Experience in Monterrey has shown that reoxidation of sponge iron is not a problem.

While the Monterrey plant will be owned and operated by Fierro Esponja, exclusive sales and licensing rights will be vested in Kellogg.



Sponge Iron production plant of Fierro Esponja, Monterrey, Mexico.

High temperature honeycomb ceramics

New Corning Glass product seen indicated for heat exchangers, catalyst supports, as high-temperature structural material.

Almost complete resistance to oxidation under continuous operation at 700°C, extreme thermal shock resistance of Cercor, new Corning Glass process material, should command close scrutiny by fabricators of chemical processing equipment.

The material, which can be based on any of a large number of ceramic compositions (including Corning's new Pyroceram) is a lightweight honeycomb structure with a bulk specific gravity of about 0.5 and a surface area of about 1,500 sq. ft./cu. ft. Melting temperature is high (1,250-1,350°C); coefficient of thermal ex-

continued on page 110

Cercor disk, 20 inches in diameter.

New polyester fiber announced by Eastman

Manufacture and mill tests of new polyester fiber were conducted in secrecy, but fiber is now on market, available for blends.

In expanding its role as a major producer of man-made fibers, Eastman Chemical Products, Inc., has now entered the polyester fiber field with a product called "Kodel." Earlier Eastman fibers included acetate (Chromspun and Estron) and modified acrylic (Verel).

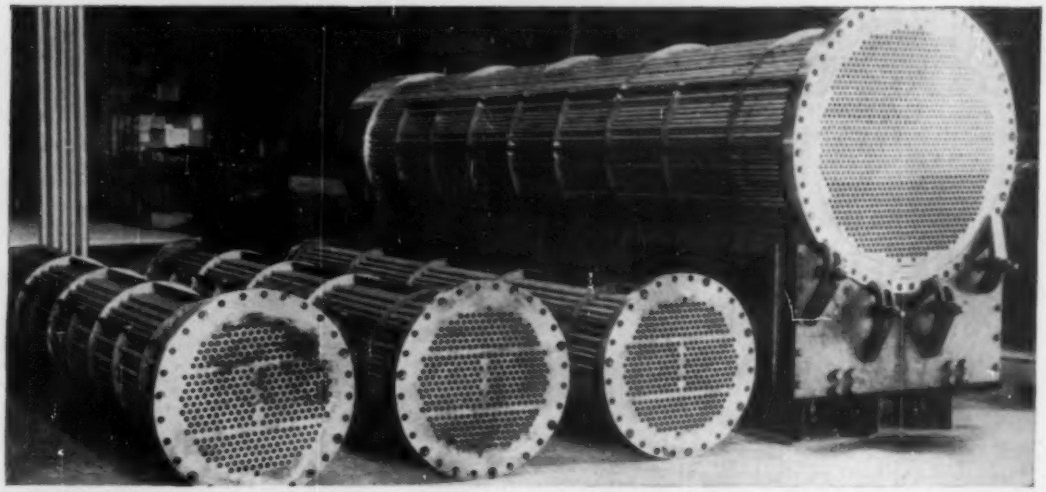
Not primarily intended for use by itself, Kodel is being introduced in fabrics with 50-75% Kodel blended with other fibers. Its use is mainly to extend the range of wash and wear fabrics.

The real story is that the fiber was tested in several mills, and by many cloth manufacturers, in secrecy before the polyester with the looked-for qualities was finally developed and put on the market.

The fiber is noteworthy for high heat resistance. Fabrics of Kodel may be safely ironed at 425°F. (which is higher than that recommended for many other man-made fibers). The fiber is not affected by acids or alkalies normally encountered by apparel fabrics, and has good resistance to common solvents and cleaning agents. Industrial applications seem feasible, but research in that direction has not been undertaken.

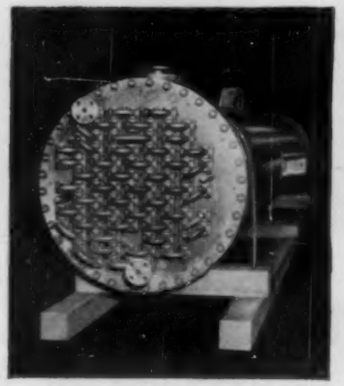
Initially Kodel will only be supplied in staple form of 1½, 3 and 4½ denier sizes. Market price to be $1.60 for the 1½ denier/filament and $1.50 for the 3 and 4½ denier.


PROPER
TOOLING

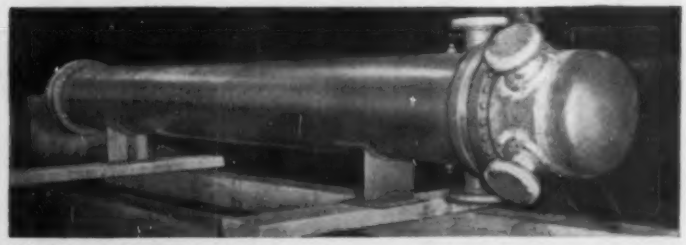


Shining example—It's all stainless steel for these four corrosion-defying bundles. We work any of the Type 300 or 400 series—have successfully rolled hard Type 329 tubes into Type 316 and 304 tube sheets.

Need unusual heat transfer experience? You'll usually find it at Downingtown



Hot and hefty—High temperature. High pressure. One tube per pass. Special Downingtown-recommended flanges, with stainless steel inserts, saved 25% of equipment cost on this 44″ D x 20′0″ L unit.



We know "Al"! And the metallurgical idiosyncrasies of welding and fabricating aluminum heat exchangers. Above: aluminum heads, tubes and tube sheets, steel shell, meet strict service conditions.

Marshaled metals—Flow sheets call for unusual metal combinations? Our engineers know how to match up suitable characteristics of each. Here stainless heads are joined with Inconel shell, tubes and tube sheets. Downingtown design saved customer 10%.

Iron Works, Inc.

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ALLOY PLATE FABRICATION
VESSELS FOR GASES, LIQUIDS AND SOLIDS

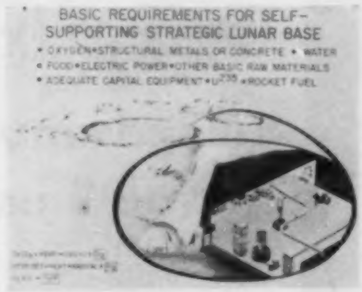
Do you have these in your file? Bulletin HE contains useful tube sheet layout tables. Bulletin CI is a handy index to the ASME Code. Write today.

High temperature

from page 108

pansion is extremely low (1 x 10^{-7}/°C from 0 to 300°C).

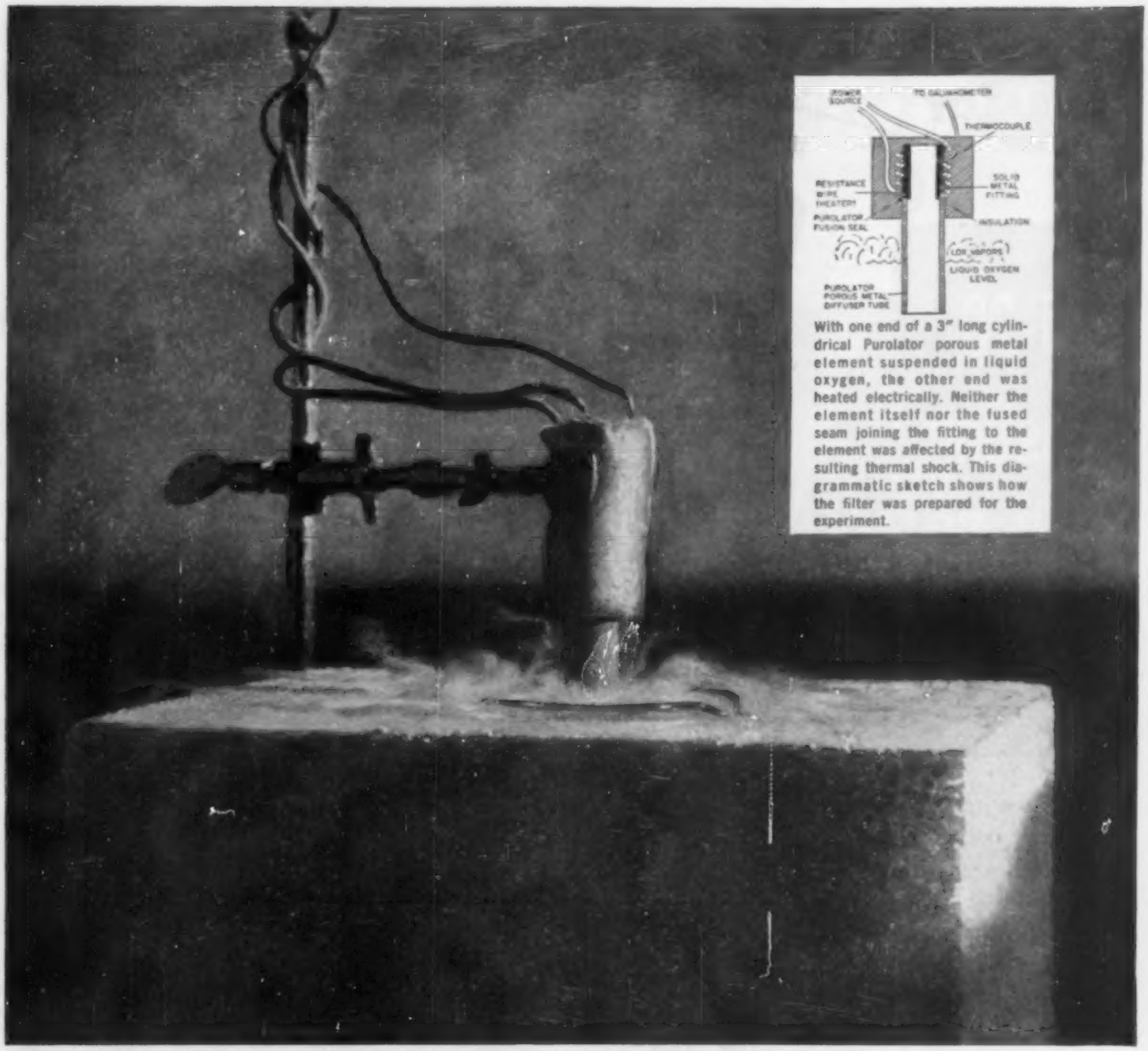
A wide range of shapes and properties is possible in Cercor materials, says Corning, which has already turned out disks 20 in. diameter by ¾ in. thick. In addition to heat exchangers and catalyst supports, Corning envisages application for air preheaters, aftercoolers, burner plates and covers, column packing material, and as an architectural material where lightness, thermal shock resistance, and high-temperature strength are required.



On to the Moon! a working model of a moon power station, powered by light from the sun, has been demonstrated by Westinghouse. In the model, a modified vacuum tube, containing the same elements that would be used in a full-scale station on the moon, absorbs a beam of light from a nearby sun lamp. Enough power is generated to drive a small motor. Basic components of an actual power station would consist only of wire mesh and a chemically-coated plastic. Giant sheets of a thin plastic material would be stretched and supported over several acres of the Moon's surface. On these sheets would be an extremely thin layer of a photosensitive material. A thin wire mesh would then be placed parallel to, but slightly separated from, the plastic sheet, and insulated from it. According to Westinghouse, generators of this type with efficiencies up to 25% are probable in the near future.

Ground has been broken at Clemson College for the S. B. Early Chemical Engineering Building which will represent a gift of $1,175,000 from the Olin Foundation of Minneapolis, Minn. The building will be completed by September, 1959.

Chemical companies are the largest givers for education, shows a recent survey by the Council for Financial Aid to Education. During 1956, $6,172,932 was given to education by twenty-four chemical manufacturing companies, the largest amount given by any one of 22 groups of companies in different fields.



With one end of a 3" long cylindrical Purolator porous metal element suspended in liquid oxygen, the other end was heated electrically. Neither the element itself nor the fused seam joining the fitting to the element was affected by the resulting thermal shock. This diagrammatic sketch shows how the filter was prepared for the experiment.

Filters for extreme conditions . . .

THERMAL SHOCK

Purolator metal filter media can take it

How much thermal shock can a filter withstand?

In a recent series of experiments, various samples of Purolator metal filter media stood up under temperature gradients, across short lengths, of up to 500°F...and could have taken more. There was no effect on filter efficiency.

Thermal shock is only one of the difficult operating problems Purolator's staff of "Q" and "L" cleared-filtration experts handle regularly. They can design and produce the exact filter needed to remove any known contaminant from any known fluid under any operating conditions. They have produced filters and separators to operate within the following wide ranges of conditions:

TEMPERATURES: from –420° to 1200°F.

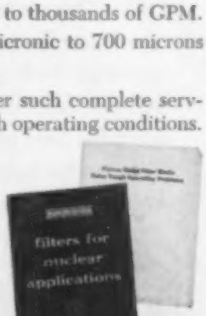
PRESSURES: from a nearly perfect vacuum to 6,000 psi.

RATES OF FLOW: from drop by drop to thousands of GPM.

DEGREES OF FILTRATION: from submicronic to 700 microns (in various media).

No other filter manufacturer can offer such complete services to handle so wide a range of tough operating conditions.

These brochures outline what Purolator can do for you, or, if you have an urgent filtration problem, call Jules Kovacs, Vice President in charge of Technical Sales . . . or send him the details of your application.



Filtration For Every Known Fluid **PUROLATOR**

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U.S. firms will aid Iran economic development

Kerman Province will be subject of intensive program to modernize exploitation of mineral resources, develop electric power potential, water supply.

Kerman Province in South Central Iran (see map), an area comparable in size to New York State, hitherto known chiefly for fine Persian rugs, may become one of the industrial focal points of the Middle East. Extensive deposits of coal, lead, copper, iron, bauxite, and chrome promise to provide the basis for a flourishing metallurgical and chemical industry.

Under terms of a recent agreement between Iran's Plan Organization and the Kerman Development Corp., jointly formed by Electric Bond and Share Co. and Allen & Co. New York banking firm, technical and management skills for the project will be provided by Ebasco Services, and financial service by Allen & Co. First step will be a preliminary reconnaisance of the territory. Then will come detailed specifications for types and sizes of facilities to be installed. For each project authorized by the Iranian Plan Organization, Kerman Development Corp. will direct and supervise engineering, design, and construction, and the testing and start-up of completed facilities, as well as training of Iranian personnel for operation of the plants.

A $4 million paint, varnish, and lacquer plant has been opened at Garland, Texas, by Sherwin-Williams Co. In the new facilities, which replace the Sherwin-Williams Dallas plant, emphasis has been placed on maximum use of automatic controls. Annual production is expected to total 7 million gallons of paint products.

SPROUT-WALDRON

Pointers

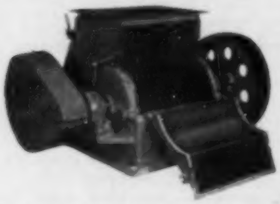
for Mixing and Blending • Size Reduction
Size Classification • Bulk Materials Handling • Pelleting and Densifying

Published in the interest of better processing by Sprout, Waldron & Co., Inc., Muncy, Penna.

PHENOLIC STOCK REDUCED IN SAW TOOTH CRUSHER

The reduction of calendered sheeting for phenolic molding compounds is being accomplished in a single pass through a heavy duty Sprout-Waldron saw tooth crusher. The warm material comes to the crusher in strips 6" to 9" wide, 12" to 18" long and in a variety of thicknesses. It is reduced to approximately ½" square pieces.

This precision-built heavy duty 16 x 25 Saw Tooth Crusher has been in successful operation at the

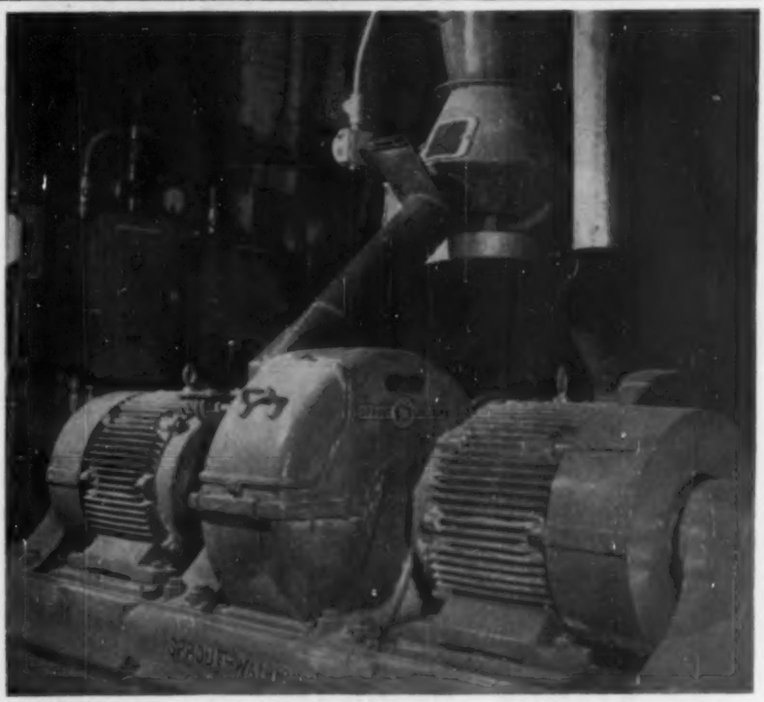


This Sprout-Waldron 16 x 25 Heavy Duty Saw Tooth Crusher has given more than 10,000 hours of satisfactory service in the crushing of phenolic stock at General Electric.

General Electric Company plant in Pittsfield, Massachusetts for over 10,000 working hours, and it is still going strong. Its hard faced 16" diameter breaker saws are designed specifically for the reduction of tough or brittle materials. In fact, everything about this crusher suggests high productivity under the most demanding conditions. Here are some of the key design points:

1. Precision-built.
2. Hinged covers to facilitate inspection or servicing.
3. Rugged construction. Alloy steel round shafts, mounted on large roller bearings.
4. Close fitting shrouds to prevent material by-passes.

For details, request Advance Specification Sheet No. 204.



STREAM SPLITTER KEEPS ATTRITION MILLS ON THE RUN

A few years ago the American Distilling Company installed a 26" Sprout-Waldron double runner attrition mill for the grinding of corn, milo, rye, barley malt and other ingredients used in the production of Bourbon Supreme Whiskey, corn and rye whiskeys and grain neutral spirits. The mill discharged into a mechanical handling system consisting of a screw conveyor and bucket elevator.

As the need for expansion became obvious it was decided to install an identical Sprout-Waldron attrition mill to operate in parallel with the existing machine, providing greater flow rate, reduced wear and simplified maintenance.

The key to the new system is a Sprout-Waldron Model VA-5 stream splitter with two outlets which divides the flow equally between the two attrition mills. Four whole grain storage bins discharge to a common Sprout-Waldron 12" x 18' screw conveyor. The center outlet of the conveyor allows the grain to pass over a magnetic separator on the way to the stream splitter. As the ground grain emerges from the attrition mills it is conveyed to the roof of the building by a Sprout-Waldron 50 hp 44" Pneu-Vac negative pressure system to another ground grain storage bin where it is held for further processing into quality whiskeys. For the facts on the Sprout-Waldron line of precision stream splitters, ask for Bulletin 137-B.

CP/106

A. I. Ch. E. candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before November 15, 1958, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Clark, Charles, Jr., *Wilmington, Del.*
Drake, Dalton F., *North Bend, Ohio*
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Freeman, Robert R., *Frederick, Md.*
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Hansen, Charles E., *Kansas City, Mo.*
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Jackson, Alfred L., *Chicago, Ill.*
James, William M., Jr., *Memphis, Tenn.*
Jarrett, Noel, *New Kensington, Pa.*
Kandel, Herbert J., *Wilmington, Calif.*
Kasbohm, M. L., *Indianapolis, Ind.*
Kvidahl, Reinert, *Green River, Wyo.*
LeRoy, J. Russell, *Denver, Colo.*
MacPherson, Gordon R., *Oakland, Calif.*
Martin, John B., *Cincinnati, Ohio*
McConnell, Jerome E., *Wilmington, Del.*
Pemberton, George M., *Cincinnati, Ohio*
Ralston, Glenn, *Maumee, Ohio*
Rankin, L. I., *Kingsport, Tenn.*
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Schirmer, Robert M., *Bartlesville, Okla.*
Schwennesen, J. L., *Idaho Falls, Idaho*
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Teyral, A. E., *Painesville, Ohio*
Tierney, John W., *Minneapolis, Minn.*
von Rosenberg, Dale U., *Baton Rouge, La.*
Walker, Leander H., *Berkeley, Calif.*
Young, Edwin H., *Ann Arbor, Mich.*

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Barnstone, Leonard, *Portland, Me.*
Bartick, Herbert, *Muncie, Ind.*
Bastone, Anthony D., *Tarrytown, N. Y.*
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Best, Frederick W., *Watchung, N. J.*
Best, Keith V., *Boulder, Colo.*
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Dallin, Edwin, *Salt Lake City, Utah*
Danly, Donald E., *Pensacola, Fla.*
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Ewing, George, *St. Paul, Minn.*
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Fries, Daniel J., *Baldwin, N. Y.*
Frischherts, Raymond, *Florissant, Mo.*
Frohlich, Gerhard J., *Cincinnati, Ohio*
Fuhs, James S., *Pittsburgh, Pa.*
Giralt, Jorge, *Havana, Cuba*
Glavan, Allen R., *Akron, Ohio*
Goins, James R., *Houston, Tex.*
Gottemoller, John V., *Niagara Falls, N. Y.*
Greer, Walter L., *Birmingham, Ala.*
Greist, Wishard Henry, Jr., *Wilmington, Del.*
Gurley, Lawrence R., *Goldsboro, N. C.*

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A. I. Ch. E. candidates

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Hagedorn, Robert J., *Oak Park, Ill.*
Hajim, Edmund A., *San Francisco, Calif.*
Hansler, Richard Stanley, *Torrance, Calif.*
Hodel, Alan Edward, *Pittsburgh, Pa.*

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Novak, Darwin A. Jr., *E. St. Louis, Ill.*

Paul, Biraja Bilash, *Baton Rouge, La.*
Pearson, Lee E., *Escanaba, Mich.*
Peterson, Randall W., *Baton Rouge, La.*
Phoa, Su Tiong, *Baltimore, Md.*
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UNFOLD CARD AND CIRCLE NUMBERS

SUBJECT GUIDE to advertised products and services

EQUIPMENT

Absorption & Oxidation Equipment. Bulletins from Turbo-Mixer Div., General American Transportation Corp. **Circle 107A-D.**

Anodes, carbon. Custom-built for individual cell requirements. Data from Great Lakes Carbon Corp. **Circle 177A.**

Castings, chrome iron and chrome nickel. Duraloy Co. **Circle 114L.**

Classifier, wet, mechanical. Catalog 39C-40 from Hardinge Co. **Circle 171R.**

Coils, heating. Bulletin 355 from Dean Products, Inc., with engineering data, Bulletin 258 with design data and prices. **Circle 189TR.**

Coils, heating. Complete drainability, easily cleaned, high heat transfer. Bulletin R-50 from Aerofin Corp. **Circle 116L.**

Coils, steam. Available in stainless steel. Bulletin M-10 from Marlo Coil Co. **Circle 15A.**

Compressors, "Isotherm." For oil-free air in large volume at medium pressure. Technical data from Brown Boveri Corp. **Circle 49A.**

Compressors, high-pressure. Single to six stages. 125 to 25,000 lb./sq. in. Catalog from Norwalk Co. **Circle 179L.**

Compressors, process. Bulletins from Cooper-Bessemer. **Circle 165A.**

Compressors, process. Engineering data

continued on page 124

MATERIALS

Amyl Alcohol, primary. Bulletin from Union Carbide Chemicals gives physical properties, shipping data, summary of uses. **Circle 131A.**

Carbon, activated. Booklet from Pittsburgh Coke & Chemical describes types and applications in liquid and vapor phase adsorption. **Circle 52A.**

Carbon, activated. Literature Group J-46 from Barnebey Cheney describes uses in purification of liquids and gases, solvent recovery, catalysis. **Circle 138L.**

Cloth, wire. Free 94-page catalog from Cambridge Wire Cloth Co. **Circle 136L.**

Coatings, protective. Details from Carboline Co. on Phenoline protective systems for concrete floors. Excellent resistance to acids, alkalis, solvents. Technical data. **Circle 143R.**

Desiccants. Technical bulletin on Molecular Sieves from Linde Co. **Circle 46L.**

Filter Paper. Information and free samples available from Eaton-Dikeman Co. **Circle 170L.**

Gases, compressed. Prices and data on 80 compressed gases and mixtures in 5 cylinder sizes. New catalog from Matheson Co. **Circle 37A.**

Heat Transfer Fluids. Booklets from Union Carbide Chemicals Co. on UCON heat transfer fluids and UCON fluids and lubricants. **Circle 10L.**

continued on page 124

SERVICES

Atomic Energy, Proceedings of Second International Conference. Information from United Nations. **Circle 157A.**

Books, nuclear technology. "Presentation Set," given to official delegates at Geneva by the U. S. Information from Addison-Wesley Publishing Co. **Circle 148BL.**

Chemical Engineering Catalog and Chemical Materials Catalog. Particulars from Reinhold Publishing Corp. **Circle 38-39A.**

Computing Service. Specializing in process simulation. Complete information from Electronic Associates, Inc. **Circle 169A.**

Customer Service. New automated communications system at U. S. Industrial Chemicals Co. speeds chemicals to customers. **Circle 19-20A.**

Design and Construction, plants. M. W. Kellogg offers booklet "Planning the New Plant for Profits." **Circle 54A.**

Design and Construction, cryogenic plants. Process research, equipment development, process design, plant operation. Details from Air Products. **Circle 117A.**

Design and Construction, sulfur from H_2S plants. Details from Ralph M. Parsons Co. **Circle IBC.**

Fabrication, process equipment. Design and fabrication to all codes. Data from

continued on page 124

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Equipment *continued from page 122*

from Fuller Co. in Bulletin C-5a. **Circle 120A.**

Computer, digital, process-control. Technical data on automatic process control and data logging from Thompson-Ramo-Wooldridge Products Co. **Circle 155A.**

Condensers, tower-type. Technical data on the Convactor from Croll-Reynolds Co. **Circle 147A.**

Controls, pH and chlorine. Handbook from W. A. Taylor and Co. on "Modern pH and Chlorine Control." **Circle 168L.**

Control Systems, visual. Twenty-four-page booklet from Graphic Systems. **Circle 189BR.**

Coolers, after. Self-contained system, independent of large cooling water supply. Bulletin 130 from Niagara Blower Co. **Circle 174BR.**

Corrosion Detectors. Data sheets from Tinker and Rasor. **Circle 172R.**

Couplings, quick. In aluminum, malleable iron, brass, other materials on request. Details from Ever-Tite Coupling Co. **Circle 26A.**

Crusher, saw-tooth. Advance Specification Sheet 204 from Sprout-Waldron. **Circle 115A-A.**

Crystallizers. Open and closed types, vacuum and cooling types for continuous operation, batch crystallizers. Bulletin CE-57 from Struthers Wells Corp. **Circle 17A.**

Deionizers. Bulletin 512 from Elgin Softener Corp. describes single-tank, mixed-bed deionizers. **Circle 164L.**

Dryers. Complete testing service available in the drying research laboratory of C. G. Sargent's Sons Corp. **Circle 142A.**

Equipment, process. Bulletins from Graham Mfg. Co. describe heat exchangers, condensers, evaporators, deaerating heaters, steam jet ejectors. **Circle 33A.**

Equipment, process. Technical data from Alsop Engineering Corp. on filtration, mixing, storage, pumping. **Circle 150L.**

Equipment, processing. Consulting services available for any process problem. Dorr-Oliver, Inc. **Circle 161A.**

Equipment, processing. Kilns, calciners, dryers, coolers. Complete systems including materials handling equipment. Bulletin 118 from C. O. Bartlett & Snow Co. **Circle IFC.**

Equipment, processing, centrifugal. Details from Kontro Co. on the Ajust-O-Film for distillation-evaporation-concentration. **Circle 125A.**

Extraction Columns. Bulletin from Turbo-Mixer Div., General American Transportation Corp. **Circle 107A-B.**

Filters. Continuous vacuum, disc, pan, plate and frame, top feed, precoat, string-discharge. Data from Eimco Corp. **Circle 11A.**

Filters. Filter presses, filter media, vertical leaf and horizontal plate filters. Technical data from T. Shriver & Co. **Circle 118L.**

Filters, metal-media. Withstands temperature gradients to 500°F., temperatures from minus 420 to plus 1,200°F., pressures from vacuum to 6,000 lb./sq. in. Technical data from Purolator Products, Inc. **Circle 113A.**

Filter Presses. Reference manual of erection, design, and construction data from D. R. Sperry & Co. **Circle 18L.**

Furnaces, industrial. For catalytic reforming, other petroleum, petrochemical, and chemical processes. Data from Petro-Chem Development Co. **Circle 137A.**

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Gauge Glass, Cylinders. Complete stock of Pyrex tubular gauge glass and cylinders. Swift Glass Div., Swift Lubricator Co. **Circle 183TL.**

Heat Exchangers. Bulletin 132 from Niagara Blower Co. describes the "Aero" heat exchanger. **Circle 154BR.**

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Heat Exchangers. Technical information from Western Supply Co. **Circle 31A.**

Heat Exchangers. Tubes and other standard components in stock for immediate delivery. M. W. Kellogg Co. **Circle 139A.**

Heat Exchangers, graphite. Data from National Carbon Co. on internal low-fin exchangers. **Circle 145A.**

Heat Exchangers, graphite, block-type. Sixteen single-block models, 4 to 350 sq. ft. Pressures to 200 lb./sq. in., temperatures to 360°F, Kearney Industries, Delanium Graphite Div. Bulletin. **Circle 170BR.**

Heat Exchangers, impervious graphite. Technical data from Heil Process Equipment Corp. **Circle 183R.**

Heat Exchangers, impervious graphite. Working pressures to 150 lb./sq. in., temperatures to 400°F. Data from Falls Industries, Inc. **Circle 182L.**

Heat Exchangers, metal and alloy. Bulletin 949 from Pfaudler Co. **Circle 151A-A.**

Heat Exchangers, plate. Operating pressures to 175 lb./sq. in. Area quickly changed by detachable plates. Data from American Heat Reclaiming Corp. **Circle 6A-B.**

Heat Exchangers, scraped-surface. Votator exchangers available in sizes of 0.7 to 60 sq. ft. of heat transfer surface. Data from Chemetron Corp., Girdler Process Equipment Div. **Circle 36A.**

Heat Exchangers, spiral. Self-cleaning, full counter-flow. Technical data from American Heat Reclaiming Corp. **Circle 6A-A.**

Heat Exchangers, tantalum. Detailed technical data from Fansteel Metallurgical Corp. **Circle 112L.**

continued on page 126

Materials *from page 122*

Heat Transfer Medium. Non-metallic plastic compound with highly efficient heat transfer properties. Data from Thermon Mfg. Co. **Circle 156L.**

Linings, fluorocarbon plastic. Durable, shatterproof, abrasion resistant, chemically inert. Bulletin AD-152 from U.S. Gasket Co. **Circle 42L.**

Packing, Teflon. Maximum temperature range of 500°F. Technical data from Flexrock Co. **Circle 174BL.**

Steel. Alloy, carbon, stainless plates, pressed and spun steel heads, fabricated steel products. Data from Colorado Fuel and Iron Corp. **Circle 141A.**

Steel, stainless. Plates, heads, rings, circles, flanges, forgings, bars, and sheets. C. O. Carlson, Inc. **Circle 119A.**

Sulfur. Technical data from Texas Gulf Sulphur Co. **Circle 40A.**

Wire, thermocouple. Over 1,500 varieties. Catalog from Thermo Electric Co. **Circle 164BR.**

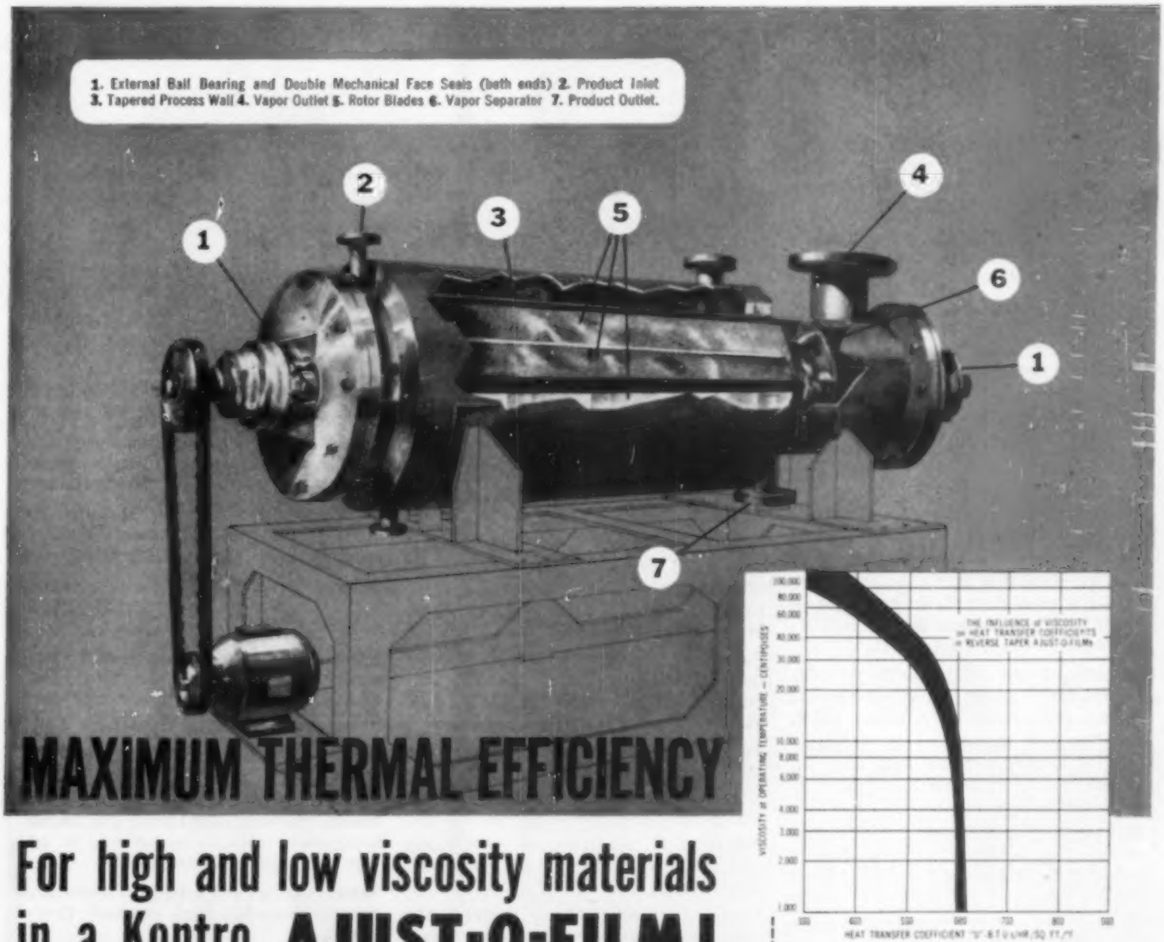
Services *from page 122*

Manning & Lewis Engineering Co. **Circle 173R.**

Fabrication, process equipment. For the nuclear, oil, gas, and chemical industries. Dresser Industries, Inc. **Circle 43-44A.**

Fabrication, process equipment. In any steel or alloy. Data from Graver Tank & Mfg. Co. **Circle 163A.**

Fabrication, process equipment. Towers, heat exchangers, process vessels in any type of stainless, other alloys. Data from Vulcan Mfg. **Circle 22-23A.**



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Equipment *from page 124*

Heat Transfer Equipment. Crystallizers, evaporators, condensers, vacuum dryers, etc. Technical data from Chicago Bridge & Iron Co. **Circle 14A.**

Heat Transfer Equipment, glassed-steel. Bulletins 921 and 886 from Pfaudler Co. **Circle 151A-B.**

Heat Transfer Surfaces, cast-iron. Catalog from D. J. Murray Mfg. Co. gives data on Grid unit heaters, blast heaters, etc. **Circle 41A.**

Heat Transfer Systems, liquid phase. High-temperature, low pressure. Bulletin 597 from Parks-Cramer Co. **Circle 179R.**

Heat Transfer Systems, liquid metal. Data from MSA Research Corp. on heat transfer systems using liquid sodium potassium alloy. **Circle 25R.**

Heat Transfer Unit. A "plug-in" electric heat transfer unit. Low pressure to 700°F. Further details from American Hydrotherm Corp. **Circle 181L.**

Indicator, liquid level. For liquid with a wide range of viscosity and specific gravity. Petrometer Corp. **Circle 181R.**

Mills, impact. Bulletins from Entoleter Div., Safety Industries, Inc. give information on free sample testing facilities. **Circle 24L.**

Mixers. Sixty-four pages of mechanical design and selection data in Catalog A-27 from Philadelphia Gear Corp. **Circle 45A.**

Mixers. General Turbo-Mixer Bulletin from Turbo Mixer Div., General American Transportation Corp. **Circle 107A-A.**

Mixers. Four-page article on heat transfer correlation in mixing vessels from Mixing Equipment Co. **Circle OBC.**

Mixers, propeller, side-entering. Bulletin from Turbo-Mixer Div., General American Transportation Corp. **Circle 107A-C.**

Nozzles, spray. Comprehensive Catalog 5600 from Binks Mfg. Co. **Circle 158L.**

Nozzles, spray, hollow-cone. Technical data from Austin Mfg. Co. **Circle 174TL.**

Packings, tower. Data on all types including Raschig rings and metal Pall rings. Bulletin TP-54 from U. S. Stoneware. **Circle 56A-B.**

Packings, tower. Raschig rings, single-partition rings, cross-partition rings, Berl Saddles. Price list from Knox Porcelain Corp. **Circle 162BR.**

Packings, tower. Intalox Saddle. Complete performance data in Bulletin S29-R from U.S. Stoneware. **Circle 56A-A.**

Piping, corrosion-resistant. Steel pipe and fittings lined with Fluoroflex-T, non-porous Teflon compound. Bulletin TS-1A from Resistoflex Corp. **Circle 16A.**

Piping, plastic. Detailed brochure from Kraloy Plastic Pipe Co. gives specifications for PVC high-impact plastic pipe and tubing. **Circle 162L.**

Piping, polyethylene, flexible. Sizes ½ to 2 in., long coils. Bulletin CE-57 from American Hard Rubber Co. **Circle 12L-D.**

Piping, rigid PVC. Schedule 40, 80, 120. In sizes from ½ to 4 in. Valves ½ to 2 in. Bulletin CE-56 from American Hard Rubber Co. **Circle 12L-A.**

Plates, hold-down, for packed towers. Use and function described in Bulletin HDP-56 from U.S. Stoneware. **Circle 56A-D.**

Preheaters, air. Technical details from Air Preheater Corp. on the Ljungstrom preheater. **Circle 133A.**

Processor, "Turba-Film." For mechanically-aided heat and mass transfer for wide range of viscous fluids and slurries. Catalog 117 from Rodney Hunt Machine Co. **Circle 48A.**

Pulverizers. Bulletin 51A from Pulverizing Machinery Division, Metals Disintegrating Co. describes the Mikro-Pulverizer. **Circle 51A.**

Pulverizers. Full details from Sturtevant Mill Co. describes the Micronizer which grinds and classifies in a single chamber. **Circle 168R.**

Pumps. For all chemical processing needs. Details from Aldrich Pump Co. **Circle 159A.**

Pumps, controlled-volume. Bulletin 440 from Lapp Insulator Co. on its Pulsafeeder with all-non-metallic construction. **Circle 35A.**

Pumps, corrosion-resistant. Durcopumps available in 12 standard alloys. Capacities from ½ to 3,500 gal./min., heads to 345 ft. Duriron Co. **Circle 21A.**

Pumps, diaphragm, controlled-volume. Pressures to 1,000 lb./sq. in., capacities from 1.1 to 138 gal./hr. Data from Milton Roy Co. **Circle 34L.**

Pumps, gear. Bulletin 17-A from Schutte and Koerting Co. **Circle 183BL.**

Pumps, gear. All wetted parts of acid-resistant hard rubber. Bulletin CE-55 from American Hard Rubber Co. **Circle 12L-B.**

Pumps, leakproof. Temperatures to 1,000°F., pressures to 5,000 lb./sq. in. Data from Chempump Corp. **Circle 129A.**

Pumps, liquefied gases. Specially-designed to handle liquid oxygen, liquid nitrogen, etc. Bulletin 203-7 from Lawrence Pumps, Inc. **Circle 140L.**

Pumps, rotary gear. Technical data from Sier-Bath Gear & Pump Co. **Circle 144L.**

Pumps, Teflon. No stuffing box or shaft seals. Catalog from Vanton Pump and Equipment Corp. **Circle 149A.**

Pumps, vertical. Bulletin 727-1 from Goulds Pumps, Inc. **Circle 127A.**

Rotameters, armored. Bulletin 19A from Schutte and Koerting Co. describes its metal-tube rotameter for hard-to-handle fluids. **Circle 180BR.**

Screeners. Data from J. M. Lehmann Co. on new scroll attachment for its Vorti-Siv. **Circle 178B.**

Seals, mechanical. Catalog 480-CEP from Durametallic Corp. **Circle 150BR.**

Separators. Custom-designed for any capacity or any special requirement. Data from Peerless Mfg. Co. **Circle 9A.**

Separators, entrainment. Bulletin 20 from Otto H. York Co. gives details of the Yorkmesh Demister. **Circle 4A.**

Sifters, rotary. Single or multiple separations down to 325 mesh. Bulletin 503 from B. F. Gump Co. **Circle 3R.**

Storage Units, liquid oxygen and nitrogen. Catalog on low-temperature apparatus from Hofmann Laboratories, Inc. **Circle 156BR.**

Stream Splitter. Bulletin 137-B from Sprout-Waldron. **Circle 115A-B.**

Support Plates, Distributors, for packed towers. Bulletin TA-30 from U.S. Stoneware gives instructions on how to select and install. **Circle 56A-C.**

Tanks, storage and mixing. Bulletin and price information from Hubbert. **Circle 180BL.**

Transmitter, liquid-level. Designed for slurries, paper stock, and viscous or corrosive fluids. Bulletin F-115 from Fisher Governor Co. **Circle 13A.**

Traps, steam. Selection, installation, and maintenance data. Catalog from Armstrong Machine Works. **Circle 32A.**

Tubing, stainless steel. Stainless steel and special alloy tubing from .050 to .625 in. O.D. Larger sizes on custom basis. Data from Tube Methods, Inc. **Circle 154L.**

Valves, alloy. Folder "Valves and Fittings in the Pulp and Paper Industry," from Cooper Alloy Corp. **Circle 50A.**

Valves, chemical. All-plastic, rubber-lined, or all hard rubber. ⅛ in. pet cocks to 24 in. gate valves. Data from American Hard Rubber Co. **Circle 12L-C.**

Waste Disposal Units. Custom-designed for individual applications. John Zink Co. **Circle 158BR.**

Weigher, continuous. Technical data from Stephens-Adamson Mfg. Co. **Circle 7A.**

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a complete new group of vertical process pumps

How often would a vertical pump be just the ticket for transfer or other service . . . *except for the fact that you're handling a corrosive liquid?*

Now you can choose from a complete line of vertical process pumps especially built for heavy-duty service, pumping corrosive liquids. Goulds now offers a wide range of vertical pumps in highly corrosive-resistant materials.

Special constructions available. Standard construction of Goulds new vertical process pumps is 316 stainless steel . . . and other materials to meet your requirements are available on application.

Free bulletin. To discover all the outstanding features of this new line of heavy-duty vertical pumps, contact your nearest Goulds representative and ask for a free copy of Bulletin No. 727-1. Or write to Dept. CEP-108, Goulds Pumps, Inc., Seneca Falls, N. Y.

GOULDS

PUMPS FOR INDUSTRY

CEP's Data Service—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 121

EQUIPMENT

301 Absorbers, hydrocarbon vapors. Bulletin from Selas Corp. of America describes the Vape-Sorber, available in 14 standard sizes.

302 Blowers, rotary positive. New design described in bulletin from Roots-Connersville Blower, features vertical arrangement of impellers to provide horizontal inlet and discharge connections.

303 Centrifuges, high-capacity. New bulletin from Centrico, Inc. covers 3 types of Westfalia automatic centrifuges—the KG/KN models for liquid clarification, the SAOG/SAMN for 3-phase separation, and the SKG/StF for continuous concentration.

304 Compressors, gas-turbine. Bulletin from Elliott Co. gives specifications, weights, dimensions, nozzle sizes, on new series of process-gas turbine compressors.

305 Controls, level. Details from Robertshaw-Fulton Control Co. on new probe-type recorder-controller-indicator unit.

306 Controls, liquid-level. New system designed by U.S. Electrical Motors, consists of Varidrive motor equipped with pneumatic Varitrol actuator. Bulletins.

307 Controllers, pneumatic. Data from Hagan Chemicals & Controls on newly-revised model of its MSP-120 Ratio Totalizer, all-purpose pneumatic control unit.

308 Cooler, tube-type. Embodies new concept in dissipating heat from fine-particle rotary kiln products. Data from Allis-Chalmers.

309 Demineralizers. Comprehensive handbook on methods of water treatment from Cochrane Corp. Typical flow diagrams, photos of installations, chemical results obtained with demineralization.

310 Dryers, vacuum, conical. "Rota-Cone" dryers, fabricated by Paul O. Abbe, Inc., are available with total internal volume of 500 cu. ft., internal diameter of 10 ft. Technical data.

311 Economizers, water. Bulletin from Mayer Refrigerating Engineers, Inc. describes industrial cooling and water recirculating units.

312 Equipment, corrosion-resistant. Twelve-page Buyer's Guide gives information on glassed-steel and alloy equipment including reactors, flush valves, new electronic glass tester. Pfaudler Co.

314 Equipment, high-pressure, bench-scale. Built for pressures to 5,000 lb./sq. in. Includes valves, fittings, reactors, autoclaves, auxiliary equipment. Bulletin 658 from Autoclave Engineers, Inc.

315 Equipment, plastic. Catalog from Raybestos-Manhattan describes full line of plastic products manufactured from Teflon and Kel-F.

continued on page 130

MATERIALS

396 Aliphatic Chemicals, use in dispersion. Armour and Co., Chemical Division, offers booklet, "Pigment Dispersion with Aliphatic Chemicals." Applications to protective coatings, plastics, and rubber.

397 Aliphatic Organic Chemicals. New catalog from Armour and Co., Chemical Division, lists specifications, applications of more than 150 fatty acids and aliphatic organic compounds.

398 Antifoams, silicone. Brochure from Hodag Chemical Corp. gives selection data, physical and chemical properties, applications, prices.

399 Carbon Wool. Available in six standard types from stock. Special grades prepared in a wide range of fiber diameters and in various physical or fabricated forms. Technical data from Barnebey-Cheney Co.

400 Coatings, protective. Bulletin from Electro Chemical Engineering & Mfg. Co. gives physical properties, lists chemical resistances of Duro-Crete, new acid-proof surfacing material for concrete.

401 Ethylene Glycol. Forty-page technical bulletin on mono-, di-, tri, and tetra-ethylene glycol is offered by Jefferson Chemical Co. Physical and chemical properties, industrial uses, specifications, analytical techniques, shipment instructions.

402 Fiber, polyester. Technical data from Eastman Chemical Products, Inc. on characteristics of its new polyester fiber, "Kodel."

403 Gases, compressed. New, enlarged edition of the Matheson Gas Catalog, offered by Matheson Co. gives data on 80 compressed gases, including new radioactive gases.

404 Indene. Reactive monomer and basic chemical Indene (C_9H_8) now available in semi-commercial quantities from Neville Chemical Co. Technical data.

405 Insulation, pipe. New development by Johns-Manville provides calcium silicate pipe insulation and aluminum jacket in single package. Designed for temperatures up to 1,200°F. Brochure.

406 Metals. New product summary and price list from Metal Hydrides, Inc., itemizes more than 30 high-purity metals, alloys, metal hydrides.

407 Plasticizers and Co-monomers. Rubber Corp. of America offers reference book with individual technical data pages on 26 plasticizers and 7 co-monomers. Also performance data, application recommendations, test methods.

408 Polyglycols. Twenty-four-page booklet from Dow Chemical titled "Choosing the Right Polyglycol." Properties, uses, toxicity data, handling precautions.

409 Rare Earth Metals. Praesody-

continued on page 132

SERVICES

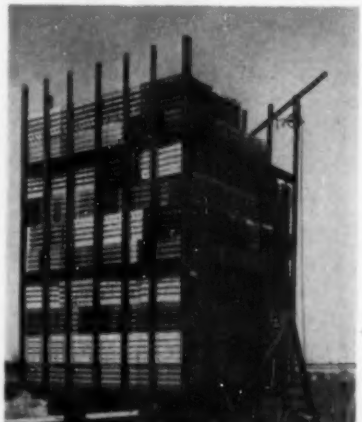
416 Fabrication, process equipment. Bulletin from Bethlehem Foundry & Machine Co. describes its facilities for design and fabrication of all types of process equipment, from autoclaves to reaction vessels.

417 Pressure Table, high-altitude. Handy pocket chart shows pressure equivalents for altitudes to about 300 miles. Kinney Mfg. Division, New York Air Brake Co.

418 Research, industrial. Brochure describes services offered by Comstock & Wescott in fields of metallurgical and chemical engineering, product and process development.

419 Technical Library Services. The Engineering Societies Library, New York, offers bibliographies, searches, translations, photoprints, microfilm, book loans. Descriptive folder available.

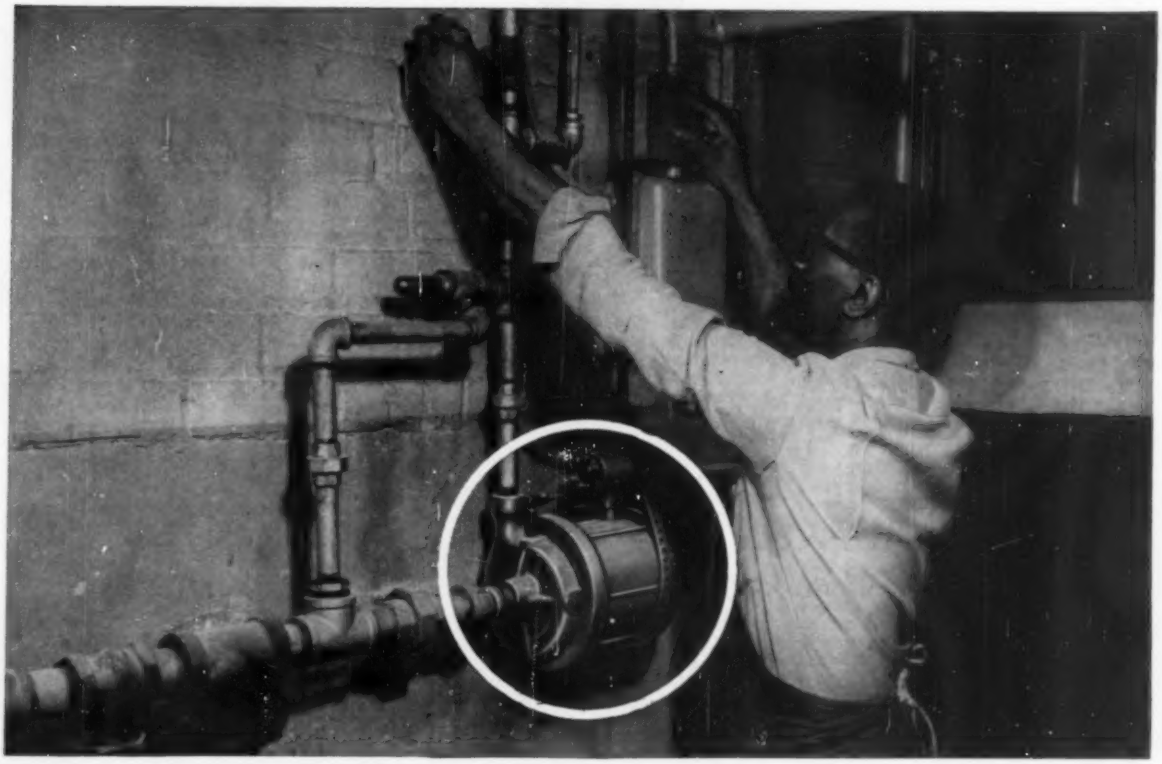
Development of the Month



PLASTIC PACKING FOR BIOLOGICAL WASTE TREATMENT (Circle 416 on Data Post Card)

A new approach to the biological treatment of liquid wastes has been developed by Dow Chemical in the form of a plastic packing material designed to improve the conditions under which micro-organisms oxidize wastes. The new product, called Dowpac, is said to have been field tested extensively in treatment of domestic sewage, wastes from metallurgical coke, kraft paper, ragmill, chemical, and petroleum plants.

Dowpac is made up of many layers of polystyrene or saran depending on the type of chemical resistance needed. The corrugated shape provides large surface areas to which waste-treating bacteria can adhere, and permits large volume air flow through the packing to supply the bacteria with the necessary oxygen. It is assembled in self-supporting units, and can be stacked as high as 42 feet. It thus requires a minimum of ground or floor area. For further information, Circle 416 on Data Post Card.



Chempump holds costs down

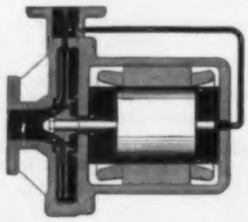
handling trichlorethylene at Argus Cameras

The explosion-proof *Chempump* shown above is one of two used at the Argus Cameras Division of Sylvania Electric Products, Inc., plant in Ann Arbor, Mich. to move trichlorethylene from storage to holding tanks.

Trichlorethylene—expensive, hazardous and highly volatile—is used here at Argus for degreasing. It's hard to hold—seeps through conventional pump packing and dissolves packing lubricants. Leakage could mean continual maintenance expense, loss of costly trichlorethylene, and the hazard of toxicity.

For Argus, *Chempump* eliminates these problems because it can't possibly leak—has no seals, no stuffing box, no packing. Simplicity of design reduces maintenance to an occasional inspection and replacement of bearings. External lubrication is never required . . . bearings are constantly lubricated by the pumped fluid itself.

You have much to gain through leakproof fluid handling with Chempump in your own processing operations. For details, write to Chempump Corporation, 1300 East Mermaid Lane, Philadelphia 18, Pa. Engineering representatives in over 30 principal cities in the United States and Canada.



Chempump combines pump and motor in a single, leakproof unit. No shaft sealing device required.

U.L. approved. Available in a wide choice of materials and head-capacity ranges for handling fluids at temperatures to 1000 F. and pressures to 5000 psi.

Chempump

First in the field...process proved

CEP's DATA SERVICE

Equipment *from page 128*

316 Equipment, process. Bulletin from Fuller Co. gives technical data on Fuller-Kinyon pumps, pneumatic conveyors, fluidizing conveyors, rotary compressors, vacuum pumps, horizontal-grate coolers, etc.

317 Equipment, process. Bulletin from Patterson-Kelley Co. gives specifications on complete line of blenders, vacuum tumble dryers, packaged resin distillation pilot plants, process heat exchangers.

322 Filter, sub-micron. For use primarily with distilled or demineralized water where it removes particulate matter down to 0.45 micron. Details from Barnstead Still and Sterilizer Co.

323 Filters, sub-micron. Bulletin from Alsop Engineering Corp. describes sealed-disc and "disc-Pak" filters, specially-designed for sub-micron filtration of machinery coolants, lubricants, hydraulics.

324 Flowmeter, high-pressure. Specification sheet from Fischer & Porter gives details of high-pressure armored flowmeter, maximum pressure rating of 2,500 lb./sq. in., suitable for elevated temperature applications.

325 Flow Meters, magnetic. Bulletin from Foxboro Co. describes "difficult liquids" which can be handled, stresses use in ratio flow control, pilot plant applications. Includes full specifications and dimensions.

326 Generators, inert gas. Bulletins from C. M. Kemp Mfg. Co. give technical data on 500 and 1,000 cu. ft./hr. panel-enclosed gas producers, and on new line of purge-gas producers.

327 Gratings. New catalog on open floor grating and stair treads offered by Reliance Steel Products. Complete engineering details, panel sizes, weights, and safe loads, surface treatments, and fastening loads.

328 Grating, aluminum. Special I-beam design allows greater loads per foot of span. Bulletin from Washington Aluminum Co. also describes facilities for fabrication of other chemical processing equipment.

329 Heat Transfer Systems, liquid. Use of organo-silicate heat transfer liquids permits operation from minus 50 to plus 700°F without pressure. Brochure from American Hydrotherm Corp.

330 Indicators, dew-point. Bulletin from Anders-Lykens Corp. describes Dew-O-metric indicators for measuring dew points of dry air or gas from minus 100°F to ambient temperatures. Dew point conversion table from high pressure to atmospheric.

331 Indicators, electronic, scanning. Digital variable indicator and temperature monitoring system can scan several hundred thermocouples at rate of five per second. Details from Hagan Chemicals & Controls, Kybernetes Division.

332 Instruments, nuclear. Complete catalog from Hamner Electronics Co. shows full line of nuclear instruments for research and industrial control. Includes basic specifications of each Instrument.

333 Instrumentation, process. Bulletin from Builders-Providence gives details of flow tubes, telemetering systems, supervisory control systems, butterfly valves, belt conveyor scales, chlorine feeders.

334 Joints, expansion. Flexible member consists of heat-resistant fiberglass-reinforced silicone casing with a heavy molded-Teflon inner liner. Pressures to 150 lb./sq. in. Details from Chicago Gasket Co.

335 Joints, pipe, flexible. Four data sheets from La Favorite Rubber Mfg. Co., contain specifications, prices, installation instructions for wire-reinforced, neoprene pipe joints.

336 Materials Handling Equipment, bulk. New 64-page catalog from Syntron Co. gives descriptions and specifications of vibrators, packers and jolters, flow control valves, etc.

337 Materials Handling Equipment, pneumatic. Pilot plant systems available for testing at minimum experimental charge. Also on rental basis. Particulars from Young Machinery Co.

338 Mills, attrition. Munson Mill Machinery now offers new line of ball-bearing mills which will grind down to 250 mesh. Technical data.

339 Mixers, portable. Bulletin from Consolidated Siphon Supply Co. gives details of new 3 speed portable mixer for stirring, blending, mixing, and agitating operations.

340 Mixers, portable. Bulletin from Jensen Engineering Co. gives tables of specifications and dimensions, describes design features, lists standard materials of construction.

341 Motors, electric, open-type. Specially designed for many applications previously requiring enclosed designs. New bulletin from Allis-Chalmers.

342 Nozzles, atomizing. Sizes, dimensions, capacities, materials of construction of new line of atomizing nozzles for quantities up to about 3 gal./min. Bulletin from Schutte and Koerting Co.

343 Oscillator, pulsed, high-power. A variable frequency pulse-modulated R.F. source for applications requiring high power output as well as extreme stability. Adapted to non-destructive testing work. Specifications from Arenberg Ultrasonic Laboratory Inc.

344 Pipe Fittings, hard-rubber. Folder from Luzerne Rubber Co. gives complete details of hard rubber pipe fittings and valves. Includes physical properties and chemical resistance of both natural and Buna-N rubber.

345 Piping, aluminum, steam- jacketed. Extruded aluminum pipe with integral steam passage now available in sizes to 6 in., up to 8 in. on special order. Data from Aluminum Co. of America.

346 Piping, cast iron alloy. Bulletin from Attalla Pipe and Foundry Co. gives sizes, dimensions, prices, weights of cast iron pipe, fittings, couplings, nipples in chrome, and nickel alloys.

347 Piping, corrosion-resistant. Engineering data booklet from Fibercast Co. covers quality control, engineering data and charts, chemical resistance, specifications, installation procedures, applications.

350 Piping, rigid PVC. Physical, thermal, electrical properties, flow rate and pressure charts. Bulletin from Kraloy Plastic Pipe Co.

351 Piping, Teflon-lined. Bulletin from Resistoflex Corp. details complete piping systems in corrosion-proof Teflon-lined pipe and fittings. Sizes, flange diameters, thickness, mounting dimensions.

352 Processor, chemical. A continuous reacter combining continuous mixing with accurate process temperature control. Working pressures to 350 lb./sq. in. gauge, temperatures from 32 to 400° F. Details from Baker Perkins, Inc., Chemical Machinery Division.

353 Pumps, centrifugal. Thirty-three sizes with capacities from 200 to 6,400 gal./min. and heads to 425 ft. Bulletin from Goulds Pumps gives specifications, sectional views, performance curves, dimensional data.

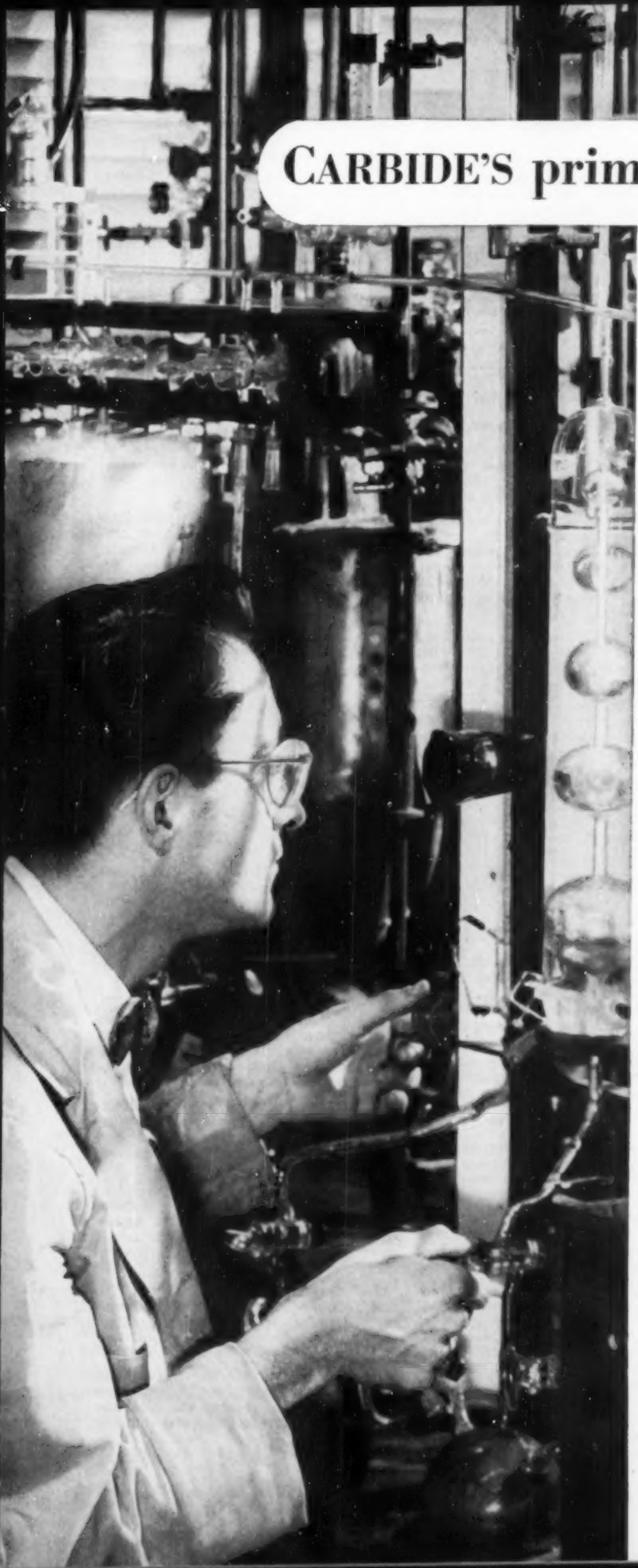
354 Pumps, centrifugal, corrosion-resistant. For the capacity range from 1

continued on page 132

Development of the Month

NEW DESIGN GRAPHITE HEAT EXCHANGER (Circle 417 on Data Post Card)

A new "compression" design, developed by Falls Industries, is said to provide 20% higher overall heat transfer coefficient than the standard shell and tube design. The entire heat transfer cylinder and dome are held in constant compression by spring loading on the floating end of the Cross-Bore type exchanger. Advantages are said to be: greater strength in the graphite parts of the exchanger, which provides increased resistance to internal and external mechanical shock, including steam hammer; ability of the exchanger to accept higher operating pressures (to 200 lb./sq. in.); more positive packing around the floating end, while at the same time permitting the heat transfer cylinder to move in the shell with greater uniformity. Cross-Bore exchangers are furnished in 14 standard models, in capacities from 24.7 to 470 sq. ft. of transfer surface. For further technical data Circle 417 on Data Post Card.



CEP's DATA SERVICE

Equipment *from page 130*

to 80 gal./min. at heads to 70 ft. Bart Mfg. Corp. will send technical details.

359 Pumps, vacuum. Data sheet from F. J. Stokes Corp. describes new series of rotary vacuum pumps. Specifications and engineering drawings.

360 Pumps, vertical, turbine-type. Complete information on specialized pumping problems available from Berkeley Pump Co.

361 Pump—Homogenizers. Positive displacement, variable volume, guaranteed leakproof, no pistons or packing, pressures to 5,000 lb./sq. in. Bulletin from Scott & Williams, Inc.

362 Pyrometers, scanning. The Thermopan, made by Radiation Electronics Corp., is capable of scanning a distant surface remotely and presenting a temperature profile on a cathode ray oscilloscope. Technical data.

363 Reducers, speed. Booklet from Link-Belt Co. contains engineering and selection data on: single reduction drives in 6 sizes, nominal ratios of 5 to 1 and capacities to 50 hp; double reduction drives in 7 sizes, nominal ratios of 15 to 1, capacities to 40 hp.

364 Refrigerator, liquid nitrogen. Stores 392 cu. in. of product at constant temperature of minus 320° F. Four-page folder from Linde Co.

365 Regulators, liquid-ratio. Type R, product of W. A. Kates Co., automatically proportions and blends a secondary stream to the measured flow of an uncontrolled primary stream, despite pressure variations. Technical data.

366 Regulators, pressure. Bulletin from Kieley & Mueller, Inc. gives extensive selection data on pressure reducing valves, back pressure and relief valves, pump governors.

367 Sampling Equipment, pipeline. Bulletin from Proportioneers, Inc. details technical aspects of pipeline sampling such as line stratification, flow profile, sample probe location, economic factors.

368 Screens. Data from J. M. Lehmann Co. on new scroll device for attachment to their Vorti-Siv. The scroll discharges automatically the tailings of any material being screened, converts from batch to continuous operation.

369 Seals, fabric, for floating-roof tanks. Brochure from Chicago Bridge & Iron details advantages of its tank seals, made of Buna-N on Nylon.

371 Structures, storage. Technical booklet from Sprout-Waldron covers wide range of storage equipment, including glass and epoxy-lined tanks, square, round, vertical, and horizontal units, related materials handling equipment.

372 Television Equipment, industrial. Bulletin from Diamond Power Specialty Corp. describes five major types, gives selection data, details case histories.

373 Thermistors, Catalog EMC-2 from Fenwal Electronics describes 15 different thermistor circuits, specifications for nearly 400 different thermistors.

374 Thermocouples. New engineering data bulletin from Thermo Electric Co. describes long, multi-thermocouple assemblies, custom built for individual applications.

375 Thermocouples, armored. Metal-sheathed, ceramic-insulated thermocouples for temperatures to 2,000°F, pressures to 50,000 lb./sq. in. Technical data from Bristol Co.

376 Thermocouple Assembles. New 36-page catalog from Conax Corp. describes complete line of thermocouple assemblies and pressure sealing glands, including several new additions.

377 Transmitter, flow-rate, pneumatic. Brooks Rotameter Co. Specification sheet gives full details of the MPT-50 which uses new magnetic conversion method.

378 Tubes, condenser and heat exchanger, wrought iron. Ten-page booklet, "Cold Drawn Wrought Iron Heat Exchanger Tubes." A. M. Byers Co.

381 Tubing, mechanical, seamless. Technical folder from Babcock & Wilcox explains selection of proper type of mechanical tubing.

382 Tubing, reactive metal. Damascus Tube Co. offers 44-page handbook on tubing for applications in chemical, nuclear, missile fields. Covers zirconium, Zircaloy 2 and 3, titanium 40, 55, 70, special steels. Also corrosion chart showing effect of 44 common corrosive solutions on these special metals.

383 Tubing stainless, rectangular. Extremely sharp corners and close dimensional tolerances; for use as wave guide. Complete information from Superior Tube Co.

384 Turbidmeter, recording. Bulletin from General Electric gives applications, principles of operation, specifications. Block diagrams show solids removal operation.

385 Unions, piping. Data sheet from Catawissa Valve & Fittings Co. gives dimensions, specifications of forged-steel, gasketless, orifice unions.

386 Valves. Condensed general catalog from Ohio Injector Co. includes valve comparison chart giving quick cross reference to most commonly-used figure numbers of ten valve manufacturers.

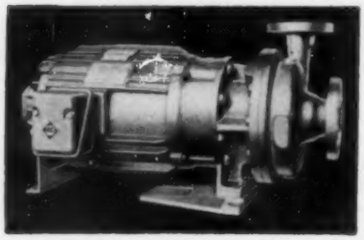
387 Valves, ball, quick-opening. Seven milliseconds full stroke operation at pressures to 4,000 lb./sq. in. and temperatures to 250°F. Technical data from Hydromatics, Inc.

388 Valves, butterfly, sizes from 2 to 24 in. in cast iron, cast alloys, or carbon steel. Complete details and specifications from Mason-Neilan.

389 Valves, butterfly. Dimensions, technical characteristics of rubber-seated butterfly valves for both tight-closing and throttling applications. Bulletin from Builders-Providence includes dimensional chart and handy sizing nomograph.

390 Valves, gate, cryogenic. For liquid oxygen, other cryogenics. Temperatures from minus 320 to plus 250°F, line pressures to 60 lb./sq. in. Technical data from Koehler Aircraft Products Co.

Development of the Month



NEW LEAK-PROOF PUMP (Circle 418 on Data Post Card)

A new single-stage, single-suction pump for leakless handling of all liquids is announced by Allis-Chalmers. Designed for handling costly or volatile substances at temperatures to 200°F., the pump is available in capacities to 500 gal./min. at heads to 250 ft.

The pump requires neither mechanical seal nor packing. Carbon sleeve bearings are impervious to most known chemical and corrosive agents. A thin-wall can, the "stator can" passes from the pump casing through the air gap of the motor to the rear housing, sealing off the stator core iron and windings from the pumped liquid. Pump and motor are a single integrated unit. Shaft, rotor, and bearings are immersed in the pumped liquid. The induction rotor, clad in corrosion-resistant stainless steel, rotates in a portion of the fluid being pumped, and is cooled by it. For more engineering data, Circle 418 on Data Post Card.

Materials *from page 128*

mium, neodymium, terbium, holmium, thulium, ytterbium, and lutetium now available in commercial quantities from Michigan Chemical Corp. Metals are cast in ingots 1, 1½, 2, 3, and 3½ in diameter, purity 99% plus. Technical data.

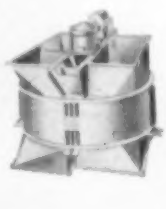
410 Resins, ion-exchange. New 17-page booklet from Rohm & Haas gives properties of Amberlite LA-1, new liquid amine anion exchange resin. Application studies, recovery and separation processes, suggested practices.

411 Resins, terpene polymer. Eight-page bulletin from Pennsylvania Industrial Chemical Corp. gives physical and chemical properties, has charts covering compatibility, solubility, and viscosity.

412 Silica Gel. Technical bulletin from Davison Chemical Co. shows characteristics of silica gel, describes methods of adsorption and dehydration.

414 Surfactants, anionic. New 16-page booklet from General Aniline & Film, Antara Chemical Sales Division, on properties and uses of anionic surfactants.

415 Thiodiglycol. Bulletin from Union Carbide Chemicals gives physical and physiological properties, specifications and test methods, storage and shipping data.



CINCINNATI—the technical program

R. F. ROMELL, *Vulcan Cincinnati*

Employment of the Chemical Engineer will be surveyed from all sides at a special panel discussion organized for Sunday afternoon (December 7), 3-5 P. M. Moderated by Jerry McAfee, the panel will include Frank Endicott of Northwestern University, A. J. Teller of the University of Florida, and Cristopher Y. Thomas, vice-president of Spencer Chemical. In the forefront of the ideas to be tossed about will be the effectiveness of chemical engineering education in the development and advancement of the chemical engineer in management as well as in the technical area.

The schedule of special events for the meeting is rounding into final shape. Supplementing the large and varied technical program (almost 100 papers) will be an extensive plant trip roster and a gala ladies program.

Starting on Sunday night, by overnight train, will be a visit of exceptional interest to Kaiser Aluminum & Chemicals' plant at Ravenswood, West Virginia. Return will be Monday evening. Also on Monday are trips to Gulf Oil, Interchemical Corp., Hilton-Davis Chemical, Emery Industries, E. Kahn's Sons Co., the Cincinnati Sewage Disposal Plant, Jos. E. Seagram & Sons Co. Tuesday's list includes Duriron Co., Formica Corp., Procter & Gamble, Rob. A. Taft Sanitary Engineering Center, and Geo. Wiedemann Brewing Co. On Wednesday, visitors may choose between Armco Steel, Formica Corp., General Electric, Emery Industries, and Geo. Wiedemann Brewing.

Activities for the ladies will get under way with the traditional Cocktail Party from 6-8 P. M. on Sunday evening. Monday offers a Fashion Presentation and Brunch at Shillito's Department Store in the morning, and a City Sightseeing Tour and Tea in the afternoon. The tour will include the University of Cincinnati, and the Zoological Gardens. Tea will be served at the Art Museum, where plenty of time will be allowed to visit one of America's finest collections of paintings and objects of art. Monday night comes one of the main events of the meeting—the Over the Rhine Party (informal dress). On Tuesday, a tour of the Cincinnati Library in the morning, lunch at the Cincinnati Club, where an illustrated talk will be given by Reed Schuster on Holiday Arrangements for the Home. The festivities will be concluded Tuesday evening by the Awards Banquet (simple dinner or cocktail dress).

Three-day Schedule

MONDAY, DECEMBER 8

2:00 to 5:00 P. M.

TECHNICAL SESSION NO. 1—KINETICS AND RATE PROCESSES.
Chairman: H. E. Hoelscher, Johns Hopkins University.

Kinetics and Mechanism of Formaldehyde Cannizzaro Reaction, C. R. Cupit, Shell Oil, & M. S. Peters, Univ of Ill. An ionic mechanism is proposed. A rate equation is derived which adequately explains the data.

The Vapor Phase Catalytic Hydration of Ethylene Oxide to Glycols, A. B. Metzner, Univ. of Del., & J. E. Ehrreich, Dewey and Almy Chemical Co. A rate equation which adequately represents the data is presented.

Diffusion Controlled Chemical Reactions, H. L. Toor, Carnegie Inst. of Tech., & S. H. Chiang, Linde. Transformations are obtained which reduce the system of differential equations for certain types of diffusion controlled reactions to the equation for pure diffusion.

On the Rate of Mass Transfer with Simultaneous Chemical Reaction in Laminar Boundary Layer Flows, Andreas Acrivos & J. D. Goddard, Univ. of Calif. The effect of chemical reactions on mass transfer in laminar boundary layer flows is studied theoretically.

Ion-Exchange Kinetics for Systems of Nonlinear Equilibrium Relationships, Chi Tien & George Thodos, Northwestern Univ. The kinetics of ion exchange has been studied in a fixed bed. Numerical solutions for the rate equations were obtained using a digital computer.

TECHNICAL SESSION NO. 2—THE APPLICATION OF COMPUTERS TO HEAT AND MASS TRANSFER PROBLEMS.
Chairman: J. M. Smith, Northwestern Univ.

The Use of an Analog Computer for Transfer Function Studies of Staged Processes, W. C. Bastian, Johns Hopkins, & L. Lapidus, Princeton. A method is presented for separating entrance and exit effect in signal response methods of analyzing processes. The method is applied to a full-scale fluidized bed unit.

Minimum Solvent Rates for Adiabatic Absorption Towers, R. L. Pigford & G. J. Davis, Univ. of Del. The solution of the differential equations for heat and mass transfer occurring in an adiabatic absorber is carried out on a digital computer.

The Evaporation of Binary Drops, J. S. Chinn, Du Pont, & W. P. Stevens, Northwestern. An IBM 650 computer is used to solve the simultaneous differential equations describing the energy and mass transfer occurring in the vaporization of liquid drops.

An Improved Solution of the Cooler-Condenser Problem Using a Large Digital Computer, A. C. Pauls, D. J. Kaufman, & Leon Cooper, Monsanto. An IBM 704 computer is employed to solve the design problem of combined cooling and condensing.

Calcuation of the Performance of a Mixed Vapor Condenser by Analog Computation, N. G. O'Brien, R. G. Franks, & J. K. Munson, Du Pont. The design of partial condensers for two condensible components is analyzed using an analog computer.

TECHNICAL SESSION NO. 3—GUIDEPOSTS TO LONG-RANGE PLANNING.
Chairman: R. W. Schramm, Union Carbide.

Significance of the Momentum Factor, R. W. Schramm, Union Carbide. The strength of present operations of a company is one of the determining factors of the type of long-range plans that should be made.

Long-Range Planning in Technical Industries, M. E. Salveson, Center for Advanced Management. Discovering and adapting business operations to the changing trends and patterns of technology and economics for more orderly progress and profit.

Integrating Scientific Research in Long-Range Planning, J. B. Quinn, Dartmouth. Presents some techniques for balanced research and development planning to fulfill the near and future technological needs of a company.

The Importance of Long-Range Facilities Planning in Chemical Operations Profitability, B. MacDonald, Jr., General Electric. The financial results of an operation are influenced directly by the effectiveness of the facilities plan. Long-range facilities planning is justified as a continuing activity by a positive contribution to profits.

Industrial Spectrum and Diversification by Acquisition, H. I. Ansoff, Lockheed Aircraft. Analyzes the entire industrial complex of the U.S. as a field for diversification and presents a method and criteria that can be used to narrow the field of interest to several select industries.

TECHNICAL SESSION NO. 4 — RECENT TRENDS IN CHEMICAL ENGINEERING EDUCATION AND ACCREDITATION (Open panel discussion, sponsored by Committee on Education and Accreditation).
Chairman: C. C. Monrad, Carnegie Inst. of Tech.

The Role of ECPD in Chemical Engineering ing Education and Accreditation, R. A. Morgen, Purdue Research Found.

The Role of ECPD in Chemical Engineering Education and Accreditation, J. H. Rushton, Purdue Univ.

continued on page 136

Know your authors for the Cincinnati Meeting

Monday Afternoon

Cupit Peters Metzner Ehrreich

Chiang Pauls Kaufman Cooper O'Brien Munson Schramm Salveson MacDonald

Ansoff Morgen Gilliland

Tuesday Morning

McKinley Kurata Sobocinski Kerry Nelson

Walker Melcher Royer

Tuesday Afternoon

Gauvin Manning Dlouhy Pinder Lee

Dwyer Chilton Leuze Howe Avrutik Nessle Grimes Shaffer Strehlow

Ward Watson Carr West Ryon Favreau

Wednesday Morning

Bialkowsky Brown

Barnhart Brady Boruff Marshall Ingebo Darnell Nelson Hill Slansky

Baczewski Levenson Gunyou Stoller Burman Leva Saltzman

Wednesday Afternoon

Walker

Talmadge Steffen Westwater Crosby Bagley Williams Updike Prados Peebles

Cincinnati program

from page 135

Training of Chemical Engineers in Chemistry. W. G. Young. Univ of Calif.

Modern Trends in Chemical Engineering Education. E. R. Gilliland. MIT.

The session will be followed by a closed meeting for consideration of confidential questions.

TUESDAY, DECEMBER 9

9:00 to 11:00 A.M.

TECHNICAL SESSION NO. 5—A.I.Ch.E. RESEARCH ON BUBBLE CAP TRAY EFFICIENCY (PART I).
Chairman: W. C. Schriener, M. W. Kellogg.

Gas Phase Mass Transfer Coefficients During Distillation in a Bubble Cap Column, C. A. Plank, Univ. of Louisville. C. E. Winslow, Virginia Smelting, & E. M. Schoenborn, North Carolina State. Tray efficiencies were determined during distillation of seven binary systems.

Gas Phase Mass Transfer Coefficients in a Bubble Cap Column, B. B. Ashby, Humble Oil & Refining, J. Begley, Esso Research and Engineering, K. F. Gordon & G. B. Williams, Univ. of Mich. Adiabatic vaporization data were obtained for nine two-component gas-liquid systems on one plate of a bubble cap column. Mass transfer coefficient, $k_g a$ was shown to be a function of F-factor, gas diffusivity, gas density, liquid density, and liquid viscosity.

Effect of Design and Operating Variables upon Gas Phase Efficiency, J. A. Gerster, Univ. of Del. N. M. Hochgraf, Esso Engineering and Research, L. E. Scriven, Shell Development, J. E. D'Evadio, Tidewater Oil, & H. Rosenhouse, Univ. of Del. Data are presented showing the effect of gas rate, liquid rate, outlet weir height, and tray design on the gas-phase tray efficiency for the absorption of small amounts of ammonia from air into water.

Liquid Phase Mass Transfer Coefficients and Liquid Mixing Parameters in a Bubble Cap Column, J. Begley, Esso Research and Engineering, G. B Williams & K. F. Gordon, Univ. of Mich. A study of liquid-phase efficiencies and mass transfer coefficients in a small bubble cap column.

TECHNICAL SESSION NO. 6—AIR COOLED HEAT ECHANGE (PART I).
Chairman: W. W. Akers, Rice Institute.

Air Cooling in Chemical Plants, R. T. Mathews, Du Pont. An evaluation of the design and performance of air-cooled equipment for refinery service.

Economics and Application of Air Fin Coolers. K. D. Segal, Esso Research and Engineering. An economic study of air-cooled equipment for refinery service.

Heat Removal—With Water or Air, B. G. Perkins, Celanese Corp. A consideration of the factors influencing the choice of air or water for heat removal.

TECHNICAL SESSION NO. 7—LOW TEMPERATURE PROCESSING.
Chairman: Clyde McKinley, Air Products.

Heterogeneous Phase Equilibria of the System CO_2-H_2S, Fred Kurata & D. P. Sobocinski, Univ. of Kansas. The complete phase diagram for the system Co_2-H_2S is described from the critical region to the triple point. Vapor density data and equilibrium constants are included.

Adsorptive Purification of Liquid Oxygen, A. C. T. Hsu & Clyde McKinley, Air Products. New data treating of the behavior of adsorptive beds in removal of contaminants present in the parts per million concentration range in liquid oxygen.

High Purity Carbon Monoxide Production, P. J. Kerry & W. L. Nelson, American Air Liquide. Performance of an operating plant for the production of pure carbon monoxide.

Status of Free Radical Research, J. L. Franklin, Humble Oil and Refining. The

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background of recently established facts concerning free radicals, especially those facts having long-range chemical engineering implications.

TECHNICAL SESSION NO. 8—SCALE-UP FROM PILOT PLANT TO PLANT.
Chairman: D. B. Coghlan, Foote Mineral.

Scale-Up Problems and Methods, John Walker, Columbia-Southern. Scale-up procedure as a criterion for choosing full-scale process components.

Projecting Blast Furnace Data to Industrial Scale-Up, N. B. Melcher & M. B. Royer, Bureau of Mines. Data from an experimental blast furnace compared with data from several industrial furnaces.

An Engineer Contractor Looks at the Pilot Plant. G. B. Zimmerman, Bechtel. The importance of having the designer of the eventual commercial plant participate in the pilot plant phase of process development.

2:00 to 5:00 P. M.

TECHNICAL SESSION NO. 9—A.I.Ch.E. RESEARCH ON BUBBLE CAP TRAY EFFICIENCY (PART II).

Chairman: J. Davies, Texas Co.

Liquid Phase Mass Transfer Coefficients in a Bubble Cap Distillation Column, C. A. Plank, Univ. of Louisville, & E. M. Schoenborn, North Carolina State. Tray efficiencies during desorption of carbon dioxide out of water with air, and during the distillation of the binary systems: acetone-water, methyl ethyl ketone-water, and methanol-toluene.

A Capillary Technique for the Measurement of Diffusion Coefficients of Binary Immiscible Systems, K. S. Howard, North Caroline State, R. A. McAllister, Lamar State College, P. P. Pike, North Carolina State, & R. Rozett, Merck.
A primary method, based on an adaptation of the classical Stefan technique.

The Effect of Temperature on the Diffusion Coefficients of Partially Miscible Binary Systems. R. Rozett, Merck, & E. M. Schoenborn, North Carolina State. Using a capillary technique, liquid diffusion coefficients have been determined over a temperature range of minus 50 to plus 25°C for five partially miscible binary systems.

Liquid Mixing on Bubble Trays and its Effect upon Tray Efficiency, D. G. Robinson, Du Pont (Canada), E. S. Dickens & J. A. Gerster, Univ. of Del., & A. B. Hill, Esso Research and Engineering. The concentration gradient of salt existing on an operating bubble tray under conditions where a salt solution is continuously injected from a vertical plane in the froth near the outlet weir. Values are computed for the eddy diffusion coefficient on bubble trays.

Effect of Design and Operating Variables upon Liquid Phase Plate Efficiency: Results for the Oxygen-Air-Water System, J. A. Gerster, Univ. of Del., A. G. Laverty & M. King, Esso Research and Engineering. The effects of gas rate, liquid rate, outlet weir height, and tray design on the efficiency of desorption of small amounts of oxygen from oxygen-rich water with air.

Tray Efficiencies for Acetone-Benzene and n-Pentane-p-Xylene Systems as Function of Total Column Pressure and Liquid Composition, N. N. Hochgraf & A. B. Hill, Esso Research and Engineering, B. Dillon, Standard Oil (Indiana), R. Hackamack, Shell Development, F. Wallis, Sun Oil, & J. A. Gerster, Univ. of Del. Pentane-xylene efficiencies may be satisfactorily predicted using the gas and liquid-phase efficiency results and liquid mixing data and equations presented in the first three papers of this series.

TECHNICAL SESSION NO. 10—SPRAY MECHANISMS (PART I).
Chairmen: J. P. Tourtellotte, Swenson Evaporator, & W. H. Gauvin, Pulp and Paper Research Inst. of Canada.

Maximum Stable Droplets in Dispersoids, R. A. Mugele, Shell Development. "Maximum stable" droplet size in non-uniform dispersoids

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may be treated as (a) non-existent, (b) a "statistical limiting" parameter, or (c) a physically significant quantity. It is shown that (c) is always permissible and in most cases advantageous, while (a) and (b) are often misleading.

Heat and Mass Transfer to Decelerating Finely-Atomized Sprays, W. P. Manning, McGill Univ., & W. H. Gauvin, Pulp and Paper Research Inst. of Canada. Transfer of heat, mass, and momentum in the nozzle zone area of sprays produced by internal-mixing pneumatic nozzles determined for both co-current and cross-current drying air flow patterns.

Heat and Mass Transfer in Spray Drying, J. Dlouhy & W. H. Gauvin, Pulp and Paper Research Inst. of Canada. Studies of the evaporation and drying rates in an experimental concurrent spray dryer are reported for various operating air temperatures.

A Study on the Efficiency of Spray Drying, K. L. Pinder & W. H. Gauvin, Pulp and Paper Research Inst. of Canada, & F. H. Knelman, Stuart Bros. Effects on capacity and thermal efficiency of spray drying equipment of variations in inlet air rate, inlet air temperature, feed temperature, nozzle location, and degree of atomization.

Chemical Reactions by the Atomized Suspension Technique, G. Lee & W. H. Gauvin, Pulp and Paper Research Inst. of Canada. A novel method for the treatment of solutions, slurries, and solids.

TECHNICAL SESSION NO. 11—REPROCESSING OF FLUID NUCLEAR-REACTOR FUELS. Chairman: O. E. Dwyer, Brookhaven.

Development of Process Methods for the Uranyl Sulfate Blanket Solution of a Homogeneous Reactor, J. M. Chilton & R. E. Leuze, ORNL. Methods being developed for recovering plutonium from the blanket solution of a two-region homogeneous reactor.

Removal of the More Noble Non-Volatile Fission Products from Uranium-Bismuth Fuels, O. E. Dwyer, Brookhaven, H. E. Howe & E. R. Avrutik, American Smelting and Refining. A process for removing nonvolatile fission products involving fused salt extraction and zinc "extraction."

Removal of Volatile Fission Products from Uranium-Bismuth Fuels, A. M. Eshaya & O. E. Dwyer, Brookhaven. The results of studies on the removal of the noble gases Kr and Xe.

Production and Handling of Molten Fluorides for Use as Reactor Fuel, G. J. Nessle & W. R. Grimes, ORNL. Methods used for purification of fluorides and for handling them without contamination.

Removal of Some Fission Products from Fluoride Fuels by Selective Precipitation, W. R. Grimes, J. H. Shaffer, R. A. Strehlow, W. T. Ward, & G. M. Watson, ORNL. Removal of undesirable fission product fluorides by precipitation techniques.

Volatility Processing of the A.R.E. Fuel, W. H. Carr, ORNL. Process in which uranium is recovered as UF_6, essentially free of fission products.

TECHNICAL SESSION NO. 12—SCALE-UP FROM PILOT PLANT TO PLANT (PART II). Chairman: R. A. Schulze, Du Pont.

Techniques of Process Evaluation, R. F. West, L. L. Yuan, W. C. McIntyre, & J. S. Hegedus, American Cyanamid. A discussion of the function of a Process Evaluation Department.

Scale-Up of Mixer-Settlers, A. D. Ryon, F. L. Daley, & R. S. Lowrie, ORNL. A method of design and scale-up for mixer-settlers for solvent extraction is confirmed by performance of two mills using the Dapex process for recovery of uranium from ores.

Analog Computers Applied to Process Design and their Relationship to Pilot Plants and Scale-Up Problems, R. R. Favreau, Electronic Associates. The role of general purpose analog computers in process design.

Design Equations for Iron Ore Reduction in a Fluidized Column with Recycles, D. L. McBride & J. F. Elliott, MIT. Equations relating

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performance with residence time, throughout and oxygen level, and their application to scale-up.

WEDNESDAY, DECEMBER 10

9:00 A. M. to 12:00 Noon

TECHNICAL SESSION NO. 13—POLLUTION CONTROL BY IN-PLANT MEASURES (PART I).
Chairman: C. F. Gurnham, Mich. State Univ.

Pollution Abatement in the Pulp and Paper Industry by Process Changes, H. W. Bialkowsky & J. C. Brown, Weyerhaeuser Timber. Modifications in pulping processes have often led to reduced pollutional loads.

Waste Reduction by Material Salvage in the Metallurgical Industries, T. F. Barnhart, Blaw-Knox. The iron and steel industry abates pollution by salvage of blast furnace flue dust, rolling mill scale, spent pickle acids, and other materials formerly discarded.

Pollution Control in the Petroleum Industry by In-Plant Measures, Sidney Brady, Humble Oil. Water conservation reduces costs for both water supply and waste disposal.

By-Product Recovery as a Pollution-Control Factor in the Fermentation Industries, C. S. Boruff, Hiram Walker & Sons. The distilling and brewing industries recover nearly 100% of their "waste" materials for use in animal feeds.

TECHNICAL SESSION NO. 14—SPRAY MECHANISIMS (PART II).
Chairmen: J. F. Tourtellotte, Swenson Evaporator, & W. R. Marshall, Univ. of Wis.

Atomization of Impinging Jets and Crosscurrent Single Jets in Air Streams, R. D. Ingebo, Lewis Flight Propulsion Lab. Photomicrographs of breakup processes for pairs of impinging jets and single crosscurrent jets.

Drop Size Distributions from Pressure Nozzles, W. H. Darnell, Du Pont, & W. R. Marshall, Univ. of Wis. Drop size distributions were found to follow a square root-normal distribution law.

Drop Size Distribution from Centrifugal Pressure Nozzles, P. A. Nelson, Argonne National Lab., & W. F. Stevens, Northwestern Univ. Methods for expressing, measuring, and correlating drop-size distribution data for centrifugal spray nozzles.

Pneumatic Atomization, J. Gretzinger, Du Pont, & W. R. Marshall, Univ. of Wis. A study of the drop sizes produced by two types of pneumatic atomizers.

TECHNICAL SESSION NO. 15—NUCLEAR FUEL PROCESSING—A CHALLENGE FOR THE FUTURE.
Chairman: J. L. Schwennesen, AEC.

Panel A: Future Chemical and Engineering Development Potentialities.
Aqueous Processes for Nuclear Fuel Processing—Past, Present, and Future, O. F. Hill, General Electric. A history of the various processes for treatment of irradiated fuels.

The Universal Process for Nuclear Fuel Recovery, C. M. Slansky, Phillips Petroleum. Consolidation of various types of aqueous nuclear fuel recovery processes into one or two basic processes shows promise.

Capital Cost Reduction in Aqueous Processing Plants, K. C. Baczewski, Blaw-Knox. The greatest potential cost reduction can come about by simplification of the "multiple head end" concept.

Potentialities of Non-Aqueous Fuel Processes, M. Levenson, Argonne National Lab. Nonaqueous processes compared with solvent extraction.

Panel Discussion—Topic A.

Panel B: When and How Will Industry Participate?

The Base Load Required to Attract Private Industry into the Reactor Fuel Processing Business, C. H. Stockman, B. F. Goodrich. It appears that a sufficient base load may come into being between 1965 and 1970.

Fuel-Cycle Costs with "Standard" Fuel Elements, E. B. Gunyou, Alco Products. Estimates of when and under what conditions the

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chemical industry may be expected to offer an economical integrated nuclear fuel service to the atomic power industry.

Problems in Industrial Operation of Separations Plants in View of Potential Hazards, S. M. Stoller, Vitro Engineering. A discussion of the hazards involved in operation of such facilities together with the severe business risks entailed.

Industrial Irradiated Nuclear Fuel Processing—Other Government Stimuli which will Encourage Industry, L. C. Burman, Engelhard Industries. The AEC should make use of the industrial services potentially available from the "hot" scrap producer, and not compete with him in the sale of radioisotopes.

Panel Dicussion—Topic B.

TECHNICAL SESSION NO. 16—AIR COOLED HEAT EXCHANGE (PART II).
Chairman: Kenneth Beatty, Univ. of North Carolina.

Finding the Optimum Air Fin Cooler Design for a Given Job, E. V. Nakayama, Phillips Petroleum. A general method for evaluating the optimum air fin cooler design.

Economics of Air Cooling in Refinery Installations Where Water is Plentiful, J. W. Thomas, Standard Oil (Ohio). Discussion of the factors influencing the choice of water or air for heat removal.

Field Performance Testing of Air Cooled Heat Transfer Equipment, J. P. Todd, Magnolia Petroleum. A method for field testing of air-cooled units.

Optimum Trim Cooler Temperature, D. Q. Kern, D. Q. Kern Associates, & R. E. Seaton, Wolverine Tube. When cooling process streams to below 140°F, an air cooler followed by a water (trim) cooler is often the most economical solution.

The Effect of Thermal Cycling to 350°F and 600°F on the Heat Transfer Performance of Integral Finned Duplex Tubes, E. H. Young & Marvin L. Katz, Univ. of Mich. The effect of thermal cycling on the thermal resistance of bi-metal finned tubes.

A Theoretical Analysis of Thermal Surface Fouling, D. Q. Kern, D. Q. Kern Associates, & R. E. Seaton, Wolverine Tube. A design method to account for transient fouling for both air-cooled and shell-and-tube exchangers.

TECHNICAL SESSION NO 17—GENERAL PAPERS (PART I).
Chairmen: William Licht, Univ. of Cincinnati, and S. C. Hite, Univ. of Kentucky.

The Geneva Conference—1958, W. K. Davis, Bechtel. A first-hand report on the second Geneva conference on peaceful uses of atomic energy.

Survey of Russian Literature in Distillation and Related Topics, H. E. Hoelscher, W. C. Bastian, & S. K. Friedlander, Johns Hopkins. Russian publications on distillation, fractionation, liquid-vapor equilibrium, etc., has been surveyed, analyzed, and critically reviewed.

A new Gas-Liquid Contacting Element—The Wetted Wall Tray, Max Leva, consultant. A new type of tray for use when liquid velocities are very low.

Kinetic Studies of the Formation of Smog Oxidants: The Ozone-1-Hexene Reaction, B. E. Saltzman, U. S. Public Health Service, & Nathan Gilbert, Univ. of Cincinnati. Basic kinetics studied with the aid of new specially-developed analytical techniques.

2:00 to 5:00 P. M.

TECHNICAL SESSION NO. 18—POLLUTION CONTROL BY IN-PLANT MEASURES (PART II).
Chairman: C. F. Gurnham, Mich. State Univ.

Good Housekeeping for the Reduction of Metal-Finishing Wastes, C. A. Walker, & J. A. Talmadge, Yale Univ. Draining and rinsing investigated theoretically and practically as means of reducing electro-plating wastes.

Control of Cleaning Wastes in the Food Industries, A. J. Steffen, Wilson & Co. Consideration of similarities and differences between processing and cleaning wastes.

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Pollution Abatement by Means of Equipment and Process Change, H. L. Jacobs & R. F. Rocheleau, Du Pont.

TECHNICAL SESSION NO. 19—HIGH SPEED PHOTOGRAPHY IN CHEMICAL ENGINEERING.
Chairman. J. W. Westwater, Univ. of Ill.

Flow Patterns in Agitated Vessels, A. B. Metzner & J. S. Taylor, Univ. of Del. Streak images in still shots of suspended. illuminated particles analyzed to determine flow pattern in viscous flow of Newtonian and non-Newtonian fluids.

Photographic Study of Solid-Gas Fluidization, L. Massimilla & J. W. Westwater. Univ. of Ill. Close-up motion pictures show the motion of individual solid particles in a bed fluidized with air.

Studies of Particle Behavior via Cine-Photography, W. H. Gauvin, McGill Univ., & S. G. Mason, Pulp and Paper Research Inst. of Canada. High-speed motion pictures show coalescence of a drop with a flat liquid surface, etc.

High Speed Camera Studies of High Explosive Phenomena, J. K. Crosby & C. H. Bagley. Stanford Research. Detonation, interacting shocks, ignition, breakup of liquid drops.

Active Sites and Bubble Growth During Nucleate Boiling, J. W. Westwater & P. H. Strenge, Univ. of Ill. Observation on bubble vibrations, irregular nucleation, and variations in bubble growth rate.

Visual Phenomena in Subcooled Boiling, A. J. Bendler, Columbia Univ. High-speed motion pictures show vibration phenomena, changes in boiling modes, motions of the heated liquid layer during subcooled boiling.

TECHNICAL SESSION NO. 20—EDUCATION IN PROCESS CONTROL.
Chairman: T. J. Williams, Monsanto.

The Needs of Industry for Persons Trained in Process Control and Process Dynamics, T. J. Williams. Monsanto. New techniques in process dynamics and process control system evaluation suffer from lack of trained personnel.

An Undergraduate Course in Automatic Process Control and Process Dynamics, J. H. Blake, Univ. of Colorado. Such a course must stress chemical process dynamics and control principles rather than instrumentation practices alone.

A Graduate Coure in Automatic Process Control and Process Dynamics in Chemical Engineering, E. F. Johnson, Princeton Univ. The course must give the student a firm grasp of process dynamics and control theory.

The Laboratory Period in the Process Control Course, O. L. Updike, Univ. of Virginia. Discussion of coordination of laboratory courses with other courses and the equipment and budgetary levels required.

Training in Industry for Process Control and Process Dynamics, W. F. Stevens. Northwestern Univ. Several industrial programs are described.

TECHNICAL SESSION NO. 21—GENERAL PAPERS (PART II).
Chairman: William Licht, Univ. of Cinicinnati.

The Mechanics of Vertical Moving Liquid-Liquid Fluidized Systems I: Interphase Contacting of Droplets Passing Through a Second Quiescent Fluid, R. E. C. Weaver, Leon Lapidus & J. C. Elgin, Princeton Univ. An extension of relations for fluidized solids to predict the hold-up of liquid-liquid spray columns from information on the single droplet terminal velocity.

Two-Dimensional Laminar Flow Analysis Utilizing a Doubly Refracting Liquid, J. W. Prados, F. N. Peebles, Union Carbide Nuclear, Univ. of Tenn. Flows about a cylindrical object, and in converging and diverging sections.

Pilot Plant Production of Synthetic Quartz, R. A. Laudise, Bell Labs., & R. A. Sullivan, Western Electric. Problems encountered in scale-up of a process for production of synthetic quartz by hydrothermal crystallization.

Gamma Gaging in Chemical Plant Instrumentation, J. A. Williamson & F. M. Teetzel, National Lead. Application of gamma radiation detection equipment to problems of level indication, flow characteristics, and density determinations in production equipment.

1958—A.I.Ch.E.

● Cincinnati, Ohio, December 7-10, 1958. Netherland Plaza Hotel. **A.I.Ch.E. Annual Meeting.** For details, see page 135.

1958—Non-A.I.Ch.E.

● Springfield, Mass. Oct. 20-22, 1958. Sheraton-Kimball Hotel. **13th Plastics-Paper Conf. of TAPPI.** To include fiber-plastics combinations.
● New Orleans, La. Oct. 20-24, 1958 and Los Angeles, Cal. Nov. 17-21, 1958. **Regional Meetings of National Association of Corrosion Engineers.** To include papers on corrosion in chemical & food processing, and petroleum industries.
● San Francisco, Cal. Oct. 22-24, 1958. Francis Drake Hotel. Amer. Vacuum Soc. **Vacuum Techniques—Theory, Applications, Processes, and Equipments.**
● St. Paul, Minn. Nov. 12 and 13, 1958. St. Paul Hotel. Fall meeting of the **Chemical Market Assoc. Adhesives.**
● Los Angeles, Cal. Nov. 13, 1958. Ambassador Hotel. **Society of Plastics Engrs.** Plastic Trends in Building Construction.
● Washington, D. C. Nov. 18-20, 1958. Sheraton-Park Hotel. **National Conference on Air Pollution.**
● Budapest, Hungary. Nov. 24-30, 1958. **International Measurements Conference.** Auspices of International Preparatory Committee. Hungarian Academy of Science acting as Secretariat.

1959—MEETINGS—A.I.Ch.E.

● Atlantic City, N. J. March 15-18, 1959. **A.I.Ch.E. National Meeting.** Chalfonte Haddon Hall Hotel. Gen. Chmn.: J. D. Stett, Dept. Mech. Eng., Rutgers Univ., New Brunswick, N. J. Tech. Prog. Chmn.: N. Morash, Natl. Lead Co., P.O. Box 58, So. Amboy, N. J. **Recent Advances in Plastic Materials of Construction**—M. P. Gigliotti, Monsanto Chem. Co., Plastics Div., Springfield, Mass. **Business & Technology**—J. Happel, NYU. **Theoretical and Laboratory Work on Liquid-Liquid Extraction**—R. E. Treybal, NYU, Univ. Heights 53, N. Y. **Laboratory and Pilot Plant Techniques**—G. W. Blum, Goodyear Tire & Rubber Co., Akron, Ohio. **Missiles, Rockets & Satellites**—G. C. Szego, Gen. Elect., Aircraft & Gas Turbine Div., Cinn. 15, Ohio. **General Papers** (2 sessions), J. Joffe, Newark Coll. of Eng., 367 High St., Newark 2, N. J. and E. C. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. **Computer Control of Processing Units**—J. M. Mozley, Johns Hopkins Hospital, Baltimore 5, Md. **Startup of New Chemical Plants**—M. L. Nadler, DuPont, Penns Grove, N. J. **Care and Feeding of Executives**—J. S. Wilson, Heidrick & Struggles, 20 No. Wacker Dr., Chicago 16, Ill. **Mechanics of Fluid-Particle Systems**—S. K. Friedlander, Johns Hopkins Univ., Balt., Md. **Process Data & Design Methods for Nuclear Fuel Recovery**—C. E. Stevenson, Rsch. Dir., P.O. Box 1259, Idaho Falls, Idaho. **Thermodynamics of Phase Equilibria**—E. M. Amick, Jr., Chem. Eng. Dept., Columbia U., New York 27, N. Y. **Market Research & the Chemical Engineer**—William Copulsky and R. Cziner, Grace R&D Co., Hanover Sq., New York 4, N. Y. **Thermal Stability of Jet and Rocket Fuels**—C. J. Marsel, NYU, Univ. Heights, New York, N. Y. **Wood as a Chemical Raw Material**—E. G. Locke, U. S. Forest Prod. Lab., Madison, Wis.

Deadline for papers: November 16, 1958.

● Cleveland, O. April 5-10, 1959. **Nuclear Congress. Co-sponsored by A.I.Ch.E. and others.** A.I.Ch.E. representative: E. B. Gunyou, Alco Prods., Inc., Schenectady 5, N. Y.

● Kansas City, Missouri, May 17-20, 1959. Hotel Muehlebach. **A.I.Ch.E. National Meeting.** Gen. Chmn.: P. C. Fowler, Consulting Chem. Engr., 7515 Troost Ave., Kansas City, Mo. Tech. Prog. Chmn.: Fred Kurata, Chem. Eng. Dept., Univ. of Kansas, Lawrence, Kansas. **Reaction Kinetics**—M. M. Gilkeson, Dept. of Chem. Eng., Tulane Univ., New Orleans, La. **How to Become a More Proficient Technical Engineer. Heavy Chemicals**—N. J. Ehlers, Columbia-Southern Chem. Corp., 1 Gateway Center, Pitts. 22 Pa. **Petrochemicals**—G. E. Montes, Nat'l. Petrochemical Corp., Tuscola, Ill. **International Licensing and Collaboration**—R. Landau, Scientific Design Co., 2 Park Ave., New York, N. Y. **General Papers** (2 sessions), J. O. Maloney, Univ. of Kansas, Lawrence, Kan. and Merk Hobson, Univ. of Nebraska, Lincoln, Nebr. **Non-Equilibrium Fluid Mechanics**—M. J. Rzasa, Cities Services Res. Lab., P. O. Box 402, Cranbury, N. J. **Role of Wetting and Capillarity in Fluid Displacement Processes**—C. S. Kuhn, Magnolia Petroleum Co., 907 Thomasson Dr., Dallas, Tex. **Thermodynamics of Jet & Rocket Propulsion**—G. C. Szego, Gen. Elect. Aircraft & Gas Turbine Div., Cinn. 15, Ohio. **Computers and Pipelines**—R. L. McIntire, The Datics Corp., 600 Camp Bowie Blvd., Fort Worth, Texas. **What's New in Liquid Metals Technology**—H. M. Rodekohr, Ethyl Corp., P. O. Box 341, Baton Rouge, La. **Ten Ways to Improve Technical Reports**—Robert Gunning, Blacklick, Ohio.

Deadline for papers: January 17, 1959.

● St. Paul, Minn., Sept. 27-30, 1959. Hotel St. Paul. **A.I.Ch.E. National Meeting,** Gen. Chmn.: W. M. Podas, Asst. Rsch. Dir., Economics Lab., Guardian Bldg., St. Paul, Minn. Tech. Prog. Chmn.: A. J. Madden, Jr., Univ. of Minn. **Mixing**—J. Y. Oldshue, Mixing Equip. Co., Inc. P. O. Box 1370, Rochester 3, N. Y. **Size Reduction**—E. L. Piret, Chem. Eng. Dept., Univ. of Minnesota, Minneapolis 14, Minn. **Missile Construction Materials**—B. M. Landis, Gen. Elect. Co., Cleveland 12, O. **Physical Properties of Liquids**—S. E. Isakoff, Dupont Co., Eng. Dept., Expr. Sta., Wilmington, Del. **Molecular Engineering**—M. Boudart, Princeton U., Chem. Eng. Lab., Princeton, N. J. **Chemical Economics as a Unit Process**—M. H. Baker, 1645 Hennepin Ave., Minneapolis 3, Minn. **More**

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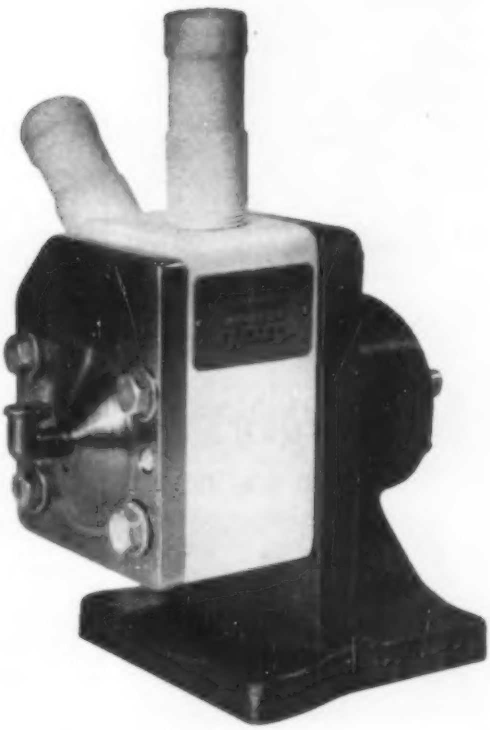
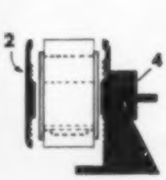
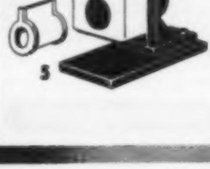
NEW!



VANTON'S NEW **TEFLON*** PUMP!

HOW VANTON DESIGN WORKS





Liquid flows in channel between molded plastic body and synthetic flex-i-liner (1) • No liquid touches metal • Liner flanges secured to plastic body by bolted face plates (2) • Pumping mechanism is rotor mounted on eccentric shaft (3) • At each revolution it pushes liner against body block and sweeps a slug of liquid around the circular track from inlet to outlet • All bearings are outside of fluid area, and located within a protective stainless steel assembly in the event of flex-i-liner failure (4) • Liners are replaced in minutes, with pump in process line, by simply removing face bolts and face plate, slipping old liner out, new one in (5).

No stuffing-box or shaft seals to leak, contaminate, or require maintenance!

Long-term maintenance-free operation even with aqua regia!

Now at last, here's a pump to solve for good your problems of pumping corrosive or abrasive liquids or slurries! HCl, caustics, $TiCl_4$, even fuming HNO_3 and fuming H_2SO_4 (oleum), all yield to the combination of Vanton's unique pump design with *Teflon and Kel-F** elastomer*, the outstanding new fluorocarbons that remain unaffected by even aqua regia!

The Vanton Pump design eliminates stuffing boxes, shaft seals, gaskets, and check valves. Previously available in many other plastics and synthetics, its appearance now in fluorocarbon materials enables it to provide prolonged maintenance-free pumping of almost any corrosive or abrasive substance in commercial production today.

All Vanton pumps are self-priming, high-vacuum, and available in a broad range of capacities from ⅓ to 40 g.p.m. In addition to Teflon, they are obtainable in 7 body and 10 flex-i-liner materials, including polyethylene, Buna N, hypalon, Kel-F, etc.

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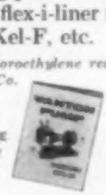

VANTON PUMP
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Research for Your Dollars—T. S. Mertes, Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa.

Deadline for papers May 27, 1959.

● San Francisco, Calif., December 6-9, 1959. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: Mott Souders, Jr., Shell Development Co., 4560 Horton St., Emeryville 8, Calif. Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem. Eng., Univ. of Calif., Berkeley, Calif. **Process Dynamics**—E. P. Johnson, Dept. of Chem. Eng., Princeton, Princeton, N. J. **Operations Research**—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. **Progress and Problems in Jet and Rocket Combinations**—C. J. Marsel, NYU, University Heights, New York 53, N. Y. **Secondary Oil Recovery Methods**—F. H. Poettman, Ohio Oil Co., Littleton, Colo. **New Oil Sources—Shale Gilsonite, Tar Sands; Financing in the Chemical Industry; Raw Materials for the Chemical Industry; Turbulence and Turbulent Mixing; High Temperature: Thermodynamics, Reactions, Kinetics; Devices, and Materials; Electro-chemical Engineering-Process Design; Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry.**

Deadline for papers: August 6, 1959.

1960—MEETINGS—A.I.Ch.E.

● Atlanta, Ga. Feb. 21-24, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: Fred Bellinger, Ga. Inst. of Techn., 225 North Ave., N.W., Atlanta 13, Ga.

● Mexico City, Mexico, June 20-24, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. E. Montes, Nat'l Petrochemical Corp., P.O. Box 109, Tuscola, Ill.

● Tulsa, Okla., Sept. 4-7, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla.

● Washington, D. C., Dec. 4-7, 1960. **A.I.Ch.E. Annual Meeting.** Tech. Prog. Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Chemical Engineering Process Dynamics as They Affect Automatic Control: David M. Boyd, 315 Ridge Ave., Clarendon Hills, Ill.

The Threatened Imbalance Between Chlorine and Alkali in American Chemical Industry: Zola G. Deutsch, Deutsch & Loonam, 70 E. 45th St., New York City 17.

Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Financing for the Chemical Industry: Bernard Stott, First National City Bank of New York City, New York, N. Y.

Chemical Engineers in Chemical Industry Management: T. P. Forbath, American Cyanamid Co., 488 Madison Ave., New York, N. Y.

Training on the Job for Industry: John Happel, Dept. of Chem. Eng., N. Y. University, University Heights, New York 53, N. Y.

Preparation of Catalytic Cracking Charge Stocks and Quality Criteria Therefor: Wheaton W. Kraft, Lummus Co., 385 Madison Ave., New York 17, N. Y.

Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

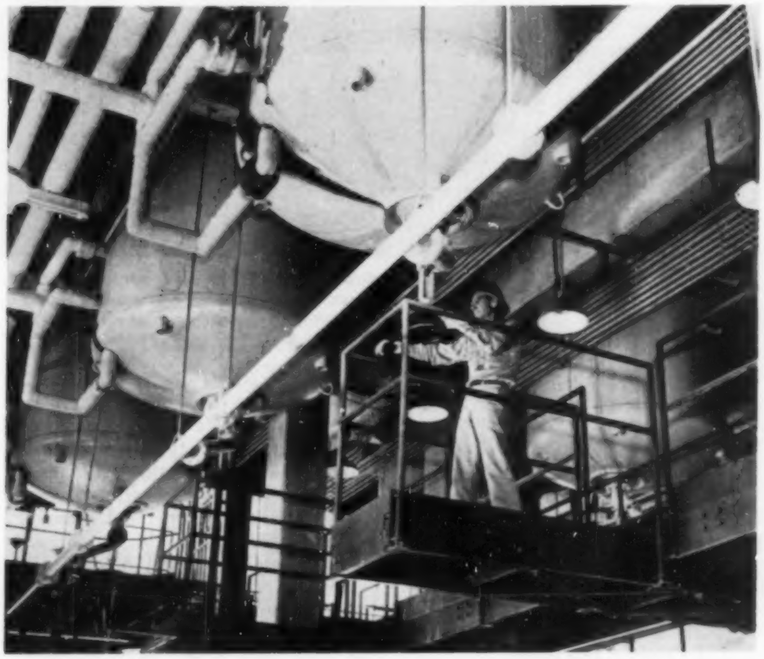
Hydrometallurgy—Chemistry of Solvent Extraction: G. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.

Mass Transfer Applications in Waste Treatment—W. W. Eckenfelder, Jr., Manhattan College, Riverdale, New York 71 N. Y.

In addition to the above, the following symposia in the management area are available from J. Happel, Dept. of Chem. Eng., New York Univ., University Heights, New York 53, N. Y.:

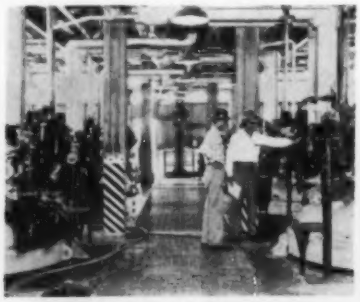
Market Research • Financing • Growth of the Chemical Industry • Distribution Between Dividends and Growth in Financing • Stock Market Analysis for Chemical Companies • International Growth.

PFAUDLER CORROSIONEERING NEWS



How Diamond Alkali uses Glasteel to cut turn-around time and protect purity at its PVC plant

Like most polymers, polyvinyl chloride gets so sticky in process that it gums up equipment surfaces to the point that a general clean-out is usually required after each batch.



Wishing to avoid such unproductive, unprofitable time at its new Deer Park, Texas plant, the Diamond Alkali Company instructed its engineers to run comparative tests on materials of construction.

Pfaudler Glasteel was the final choice and Diamond Alkali uses it wherever possible in the new plant . . . for polymerizers, blow-down tanks, storage and receiver tanks, and even for pipes and valves.

So little of the PVC clings to the smooth glassed surfaces of this equipment, a simple fast flush is all that's necessary to keep it in process condition.

During two years of operation, on a twenty-four hour a day basis, production has been halted only for routine maintenance.

Protects purity too

Pfaudler Glasteel is chemically inert to the ingredients and catalysts used in making PVC . . . so there can never be any contamination of Diamond Alkali's product.

Special agitator seals on the polymerizers prevent any lubricants from bleeding into the product.

The equipment is so designed and controlled that Diamond Alkali can hold temperatures to within ½° F. of a desired setting.

If you would like to know more about Pfaudler Glasteel and the equipment made with it, check the coupon for our Bulletins 968 and 932.

Big zirconium and titanium heat exchangers now available

Recent addition of vacuum-purge inert gas welding to the already established flow-purge inert gas welding chamber shown above, places Pfaudler in the advantageous position of offering the most advanced facilities for welding the highly corrosion-resistant metals, titanium and zirconium. Now several hundred square feet of heat transfer surface can be more economically and rapidly produced.

Add these metals to your list of available Pfaudler materials for fighting corrosion in process equipment—an ever growing list that already includes Glasteel, stainless steel, Hastelloy, nickel, Inconel, and Monel.

The unit being worked on in the picture is one of the largest zirconium exchangers built to date, having 134 square feet of heat transfer area. Sixty-four 1" O.D. 18 gauge seamless zirconium tubes in a 21" O.D. shell 8' long. Designed for 75 psi and 350° F. it forms the calandria section of an evaporator for concentrating hydrogen peroxide solutions.

Pfaudler Bulletin No. 949 describes the complete line of metal and alloy heat exchangers. Heat transfer equipment of Glasteel construction are covered in Bulletins No. 921 and No. 886. Send the coupon for copies.

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Chemical engineering in the industrial development of boron hydrides

Lewis A. Barry,
Callery Chemical Company, Callery, Pennsylvania

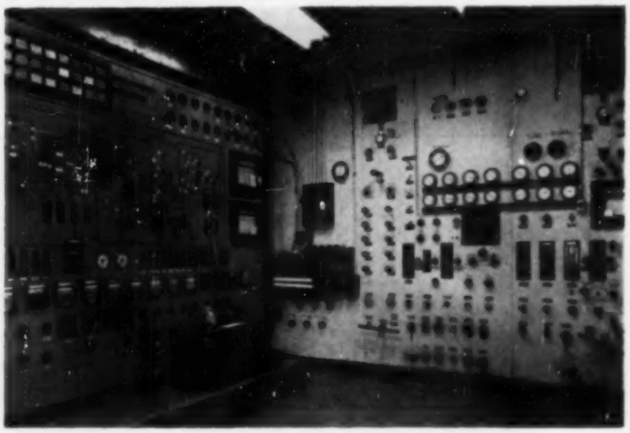

Figure 3. A control room of a typical pilot boron hydride plant. The process units are behind the wall on the right. Remote controls and automatic instrumentation on left.

The boron hydrides represent potentially one of the best "packages" for concentrating chemical energy. Although this suggests a useful source of energy stored, these materials cannot be considered as a basic source. Much expensive and difficult processing is necessary to produce boron hydride compounds. The over-all process energy efficiency is in the order of only a few per cent. For certain specialized applications, however, where concentrated chemical energy, high reactivity, and rapid availability are required, such as fuels for missiles and aircraft, the boron hydrides appear to be superior to most other energy sources.

Technology

The task of developing a feasible process for the production of boron hydrides is not a simple one. The chemistry is complex. Despite the research and development activity in the field, little is really known. Here are some of the problems which confront the chemical engineer in the development of large-scale commercial processes.

Three characteristics of boron hydride create most of the problems for the chemical engineer and tax his ingenuity to the utmost. These are:

1. Extreme reactivity
2. Moisture and air sensitivity
3. Toxicity

Reactivity. Most of the lower boron hydrides react vigorously with oxidizing compounds, water, alcohols, acids, organic unsaturates, and almost all substituted organics containing any type of functional group. Many of the boron hydrides have spontaneous ignition temperatures below ambient. Consequently, when there is a leak in a system, there is usually an accompanying fire and sometimes an explosion. Because of this, operating units are usually isolated and remotely operated or operated through protective barricades. This, of course, greatly complicates and hinders development programs.

At Callery, bench-scale units are mounted in cell enclosures, usually on the steel plate walls. Valve handles, sample points, and meter faces pass through the walls or are set in front of openings. The unit is operated from outside the enclosure. Some typical bench-scale-unit construction is shown in Figures 1 and 2. Pilot plant units, under roof, are designed similarly to the bench-scale units. However, because they are larger and more complex, it is impossible to operate and control them entirely through the steel walls of the enclosure. This technique is supplemented with considerable remote instrumentation and control. A

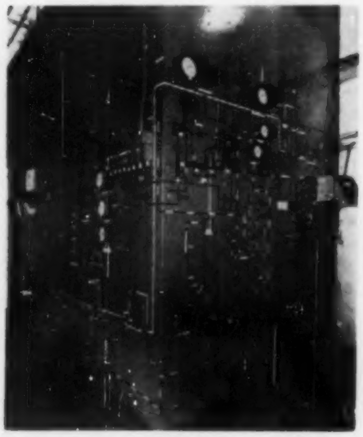

Figure 1. The outside of a typical bench scale experimental unit used by Callery in development work on boron hydrides.

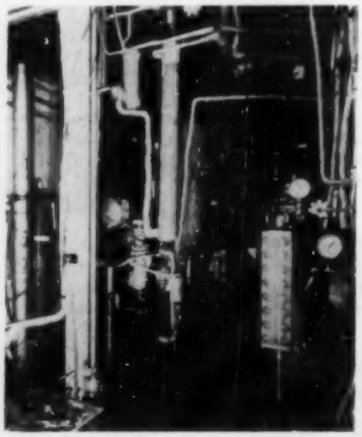

Figure 2. Inside view of the same bench scale unit shown in Figure 1, revealing equipment attached to steel wall.

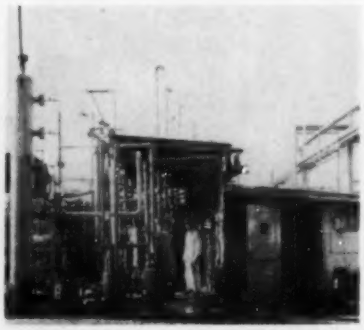

Figure 6. One of Callery's typical outdoor pilot plants used in development work on the difficult boron hydrides.

typical pilot plant unit at Callery is shown in Figures 3, 4, and 5. When conditions permit, pilot units are mounted outdoors and operated through the wall of a control house and by remote instrumentation. This technique is highly desirable but not often convenient when one is doing experimental work which demands frequent system redesign and rebuilding. Figure 6, illustrates a typical outdoor pilot plant unit.

When work is going on with boron hydrides, because of their extreme reactivity, fires and explosions are a continual hazard. Most common fire extinguishants are not effective on boron hydride fires. Many are violently reactive with boron hydrides. Water and some new foams have been found to be moderately effective. It is not safe to try to extinguish a boron hydride fire in confined space. Decomposition of the released hydride usually continues. This generates hydrogen which, in confined areas, creates an even greater hazard. It has been found that the safest thing to do on such a fire is to cut off the source of supply of the hydride and try to use extinguishers to confine the fire. Explosion protection is obtained by the use of enclosures and barricades previously described and also by the use of soft wall and blowout panel type of construction. Figures 7, 8 and 9, show examples of this type of construction at Callery.

Moisture and Air Sensitivity Most of the boron hydrides and derivatives are readily decomposed by air and moisture. The lower hydrides decompose rapidly accompanied by a vigorous and sometimes violent reaction. The higher hydrides react more slowly. Products of decomposition are various partially oxidized and hydrolyzed compounds and, finally, hydrogen and boric acid. Many decomposition products are solids which deposit in operating systems causing plugs. Others cause damaging corrosion.

As a result of this, it is necessary that all parts of a process unit be completely sealed and the atmosphere always excluded. An inert gas blanket must be employed. Nitrogen is the most satisfactory blanketing gas. This means that a nitrogen generating unit is always a necessary auxiliary to a boron hydride plant.

When the system has been opened for maintenance, it is necessary to completely exhaust all traces of air and thoroughly dry it out. A common procedure is to flush the system with volatile cleaning and drying solvents then follow this with a hot dry nitrogen purge. Pumping with vacuum pumps is frequently used on small units.

All vents must be sealed using seal pots, check valves or regulators, to prevent atmospheric contamination. Vents are usually manifold and tied to a regulated nitrogen supply for breathing. This includes storage and

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Figure 4. (Left) Another typical control room with the process sample, purge points, and valves mounted on the steel wall, left.

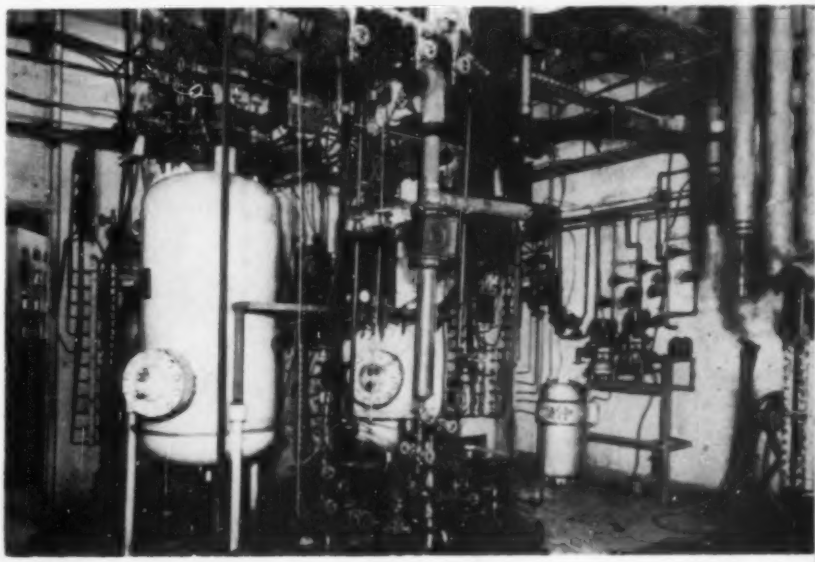

Figure 5. (Below) Process side of control room in Figure 4 above.

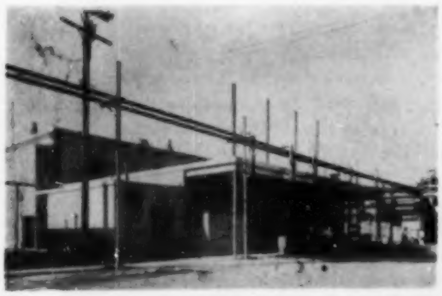

Figure 7. Explosion-proof "soft wall construction" at Callery. Corrugated steel sheet panels are clipped on so they will yield to an explosive pressure.

Figure 8. Transit panels are used in another type of explosion-proof, soft wall construction.

Figure 9. An earth-filled revetment is used as an explosion resistant barricade. The walls are 4 ft. thick at bottom, 2 ft. at top.

Boron hydrides

Continued from page 153

surge tanks.

Because of the moisture and air sensitivity and reactivity, vacuum systems should not be used in plant operations on boron hydrides. A leak may not only cause decomposition of the material in the system, corrosion, and plugging, but it may also cause an explosive reaction inside the system which will make missiles out of parts of the equipment. Copious use of vacuum breakers on all parts of the system, particularly blowers and compressors, is necessary.

Toxicity In general boron hydrides are quite toxic. An extensive study of the toxicity of these compounds has been included in Callery's research and development program. This study reveals that the boron hydride gases and vapors are much more toxic than hydrogen cyanide, hydrogen sulphide, phosgene and several of the chemical warfare agents. Methods for detection of traces of boron hydrides in the atmosphere have been developed by Callery. One of these has

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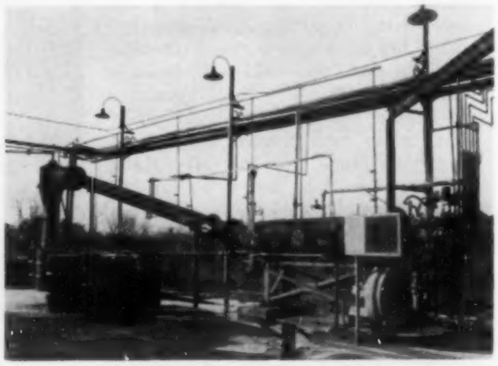

Figure 10. In this waste disposal burner the flue gases are scrubbed by a venturi scrubber mounted on a collection sump.

industrial news

Boron hydrides

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been converted into an automatic monitoring device which is available commercially.

To minimize the effect of atmospheric contamination on operating personnel, process enclosures are maintained under negative pressure while the operating area outside the cells are maintained at a positive pressure. Approximately 40-60 air changes per hour are maintained inside process enclosures.

Operating personnel who work inside of cell enclosures are provided protection is by Chemox gas masks for prolonged service, and adsorbent with protective clothing. Respiratory cannister type of masks for short periods of service.

Boron in concentrations above a few parts per million is toxic to most plant and stream life. Because of this, waste disposal and soil contamination are also a serious problem. Combustible boron containing wastes are burned in especially designed burners

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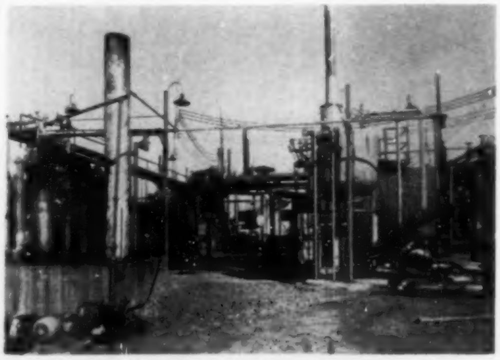

Figure 11. In this waste concentration system, a submerged combustion burner on the right concentrates waste from the scrubber sump.

Boron hydrides

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and combustion chambers. Flue gasses are scrubbed free of boron. All process vents are also scrubbed. Aqueous boron containing wastes may be disposed of in rivers if the river flow is great enough to keep concentration below a few tenths of a part per million. If this is not possible, aqeous wastes must be concentrated and hauled away for safe disposal. Figures 10 and 11 show some of the waste disposal and scrubbing systems employed at the Callery plant.

Materials of construction

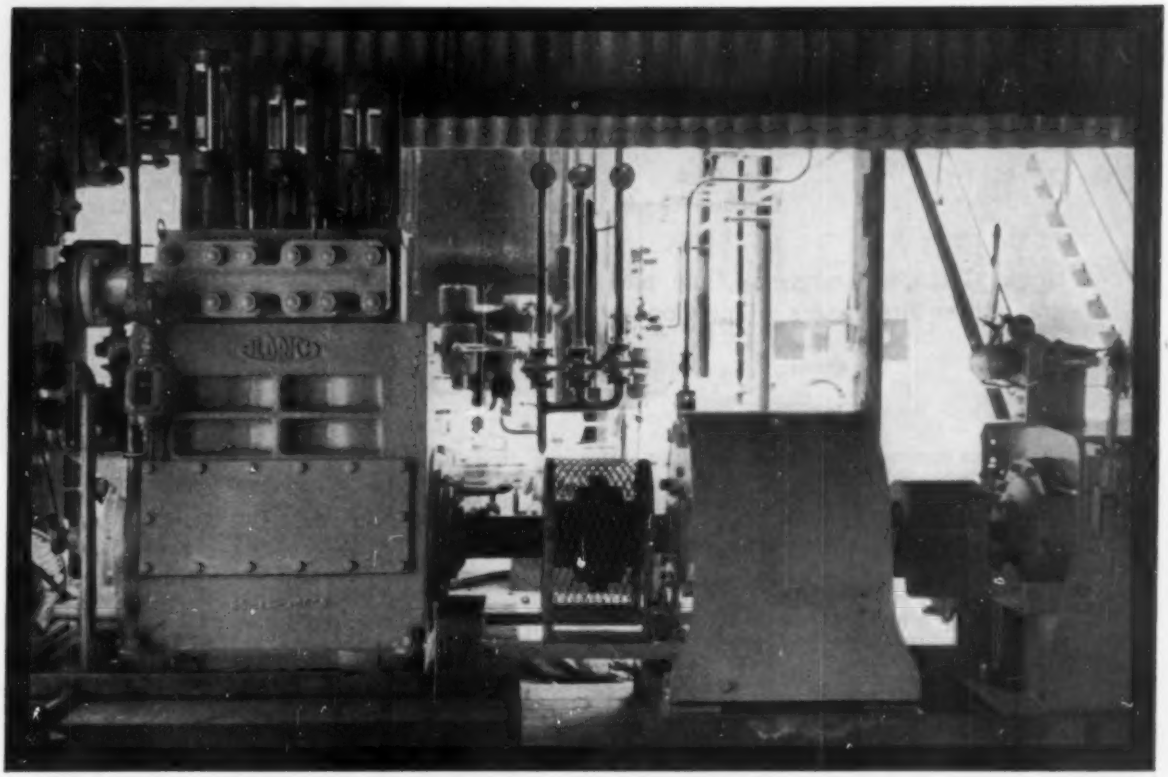
All metals with the exception of aluminum and magnesium and their alloys are satisfactory for use with boron hydrides. Mild steel, copper, and brass are most commonly used.

Most rubber and plastic materials are attacked by boron hydride compounds. This presents serious gasket and seal problems especially at high pressures. Some asbestos compounds, teflon, Kel-F, and metals are widely used as gasket materials.

Most boron hydrides have extremely low viscosity and surface tension. Because of this, screwed fittings are not very satisfactory for many applications. Welded and flanged pipe and tubing are preferable. Because of these same properties, and the fact that they are miscible with most inert liquids, many boron hydrides are classed as anti-lubricants. They seriously impair the lubricating properties of most common lubricants. This presents some severe problems with pumps and compressors. Special lubricants are being developed for such service.

It is evident that the development of boron hydride production processes has been beset with many problems. These have taxed the resources and ingenuity of the chemical engineer. However, most of them have been solved. The rest are rapidly disappearing. There appears to be little doubt that in the near future these compounds will be as plentiful and as cheap as most other widely used compounds for comparable applications. Because of their high potential energy and strong reducing properties, they will probably continue to find their widest application as special fuels, fuel additives, special industrial reducing agents and antioxidants.

Presented at 1958 A.I.Ch.E. meeting, Salt Lake City, Utah.



Closed-Circuit TV Aids Process Control

Tom Shea,
Blonder-Tongue Laboratories

Union Carbide, Brunswick Pulp and Paper are among first users of new operating tool.

Figure 1—Typical receiver installation.

Closed-circuit TV is a communications device. The views presented through the camera and the receiver expand the range of human observation. The goals may be: safety of personnel; protection of equipment and materials through remote observation of gauge readings; composition, flow, or position; or quality control through remote inspection of products or materials. No Federal license or other special franchise is necessary. Most industrial process control applications present fixed views, and installation and maintenance is usually no more complicated than that required for home TV.

Basic equipment consists of a camera, the lens, a control generator, a multi-conductor cable to connect the camera and generator, and a conventional TV receiver (Figure 1). Where fine detail viewing is required, such as printed matter or small parts inspection, the standard TV set would be replaced with a studio-type monitor providing twice the resolution. More elaborate systems may be required in certain process control systems.

Pulp and paper takes lead

The pulp and paper industry has been one of the leaders in applying closed-circuit TV to process control systems. Both Ketchikan Pulp at Ward Cove, Alaska, and Brunswick Pulp and Paper at New Brunswick, Georgia, have incorporated cameras to insure against breakdowns due to possible overflow or congestion.

Ketchikan needed visual control of chip levels in three 50 ft. diameter surge bins to ensure proper feed and composition of wood chips. Installation of a closed-circuit chain enables one operator to view these levels from the comfort of a remotely located control room. Normal plant lighting is adequate for the camera head, which is housed in a standard weather-protected enclosure.

Television was an integral part of the original design of the new $3 million bleach plant of Brunswick Pulp and Paper. Provision was made for a 5-camera, 5-monitor network. Three cameras view pulp discharge from 11 ft.-6 in. by 20 ft. pulp washers (Figure 2); one camera views the intake or vat side of one washer; and the fifth pickup point is the pulp feed point from the belt conveyor onto the distributing conveyor chute. All cameras employ standard 16 mm., F1.9 lenses, and are housed in protective enclosures. Coaxial cables feed the control-room monitors through 5-position switches (Figure 3).

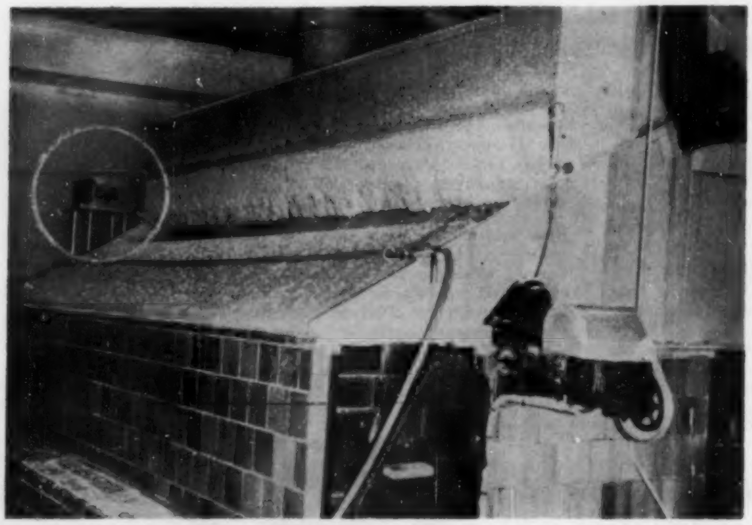


Figure 2—Observer TV camera mounted in protective housing and focused on pulp washer discharge side.

Safety is keynote

Safety of operating personnel was the deciding factor behind installation of closed-circuit TV at the South Charleston, West Virginia, plant of Union Carbide Chemical, where a 2-camera chain observes operators in hazardous areas. For complete protection, it was considered advisable to install one camera at ground level, and another at a sixty-foot elevation. The cameras are enclosed in vapor-proof housings, and all cables are run in conduits. As an added precaution, each camera is purged with a small amount of instrument air to keep it cool and under positive pressure.

Versatility

Complete remote control and system versatility can be obtained by use of the following accessories to the basic camera equipment:

- Zoom Lens, with variable focal length from 1 to 6 in.

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TV process control

from page 160

• Pan & Tilt Mechanism, used as the camera mount. Provides 2,000 ft. distant remote control of 360° horizontal rotation and 45° vertical rotation of the camera. For area scanning.
• Weather-Proof Housing. Provides remote control of windshield wiper, heater, and blower.
• Automatic Light Compensation. Allows constant picture quality regardless of light level changes within range of 150 to 1 at the area under surveillance.
• Remote Focus Control. Provides adjustment of camera at distances up to 2,000 ft. when objects from 2 ft. to infinity are to be viewed.

It may be desirable to feed several cameras to one or more viewers. This is accomplished by having each camera on a different channel, carried on a common transmission line. Multiple outlets or viewers are then provided for by "tapping off" from the main or branch coaxial cable runs (Figure 4). Sound may also be added by separate intercom system where few receivers are involved, or by special audio-video systems which provide

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Figure 3—Monitors located in bleaching plant control room.

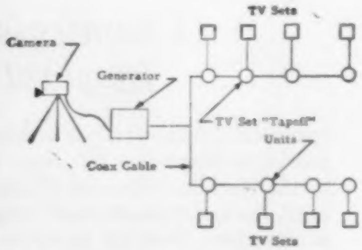
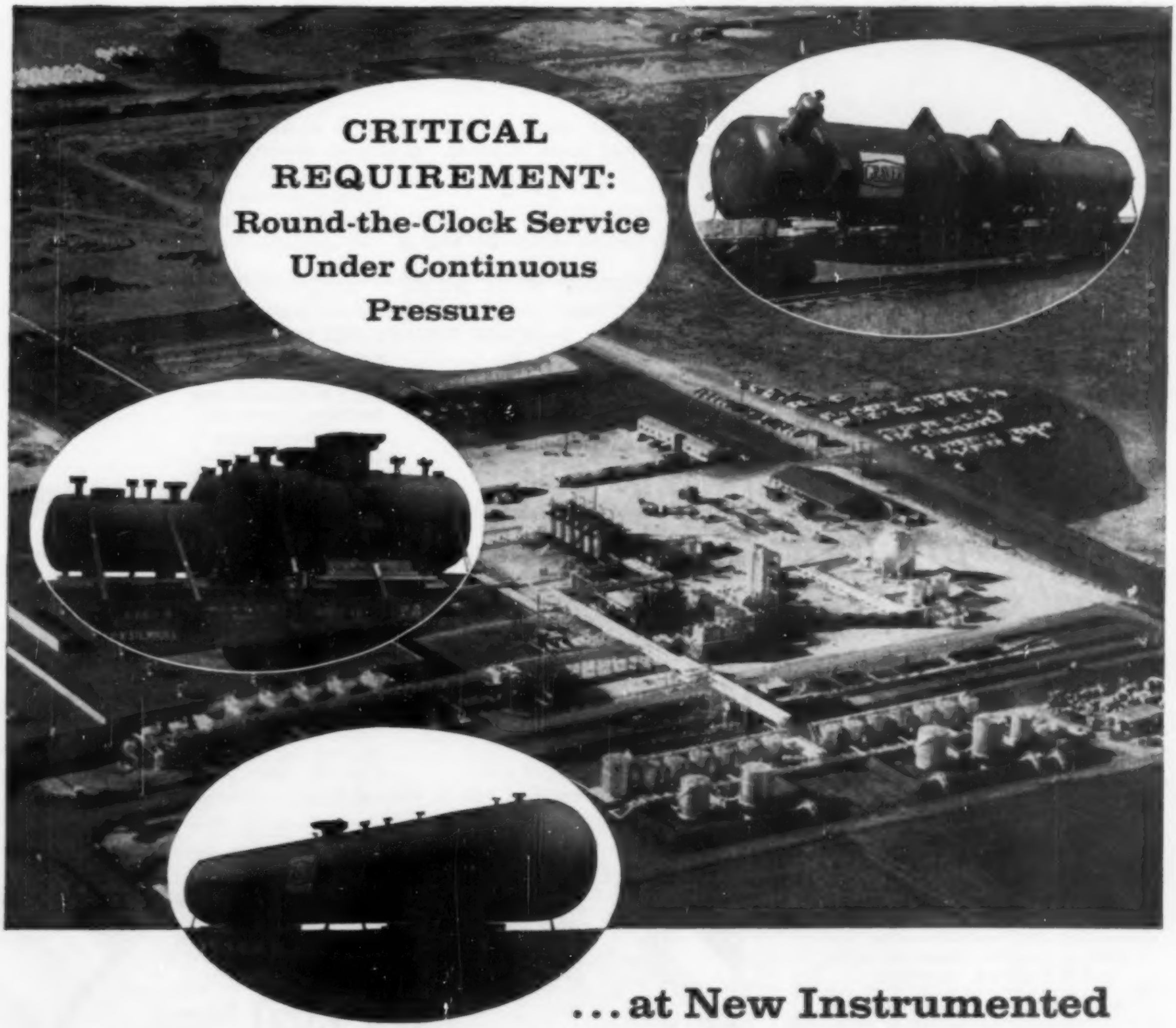


Figure 4—Typical closed circuit television distribution system.



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Eighteen pressure vessels fabricated by Graver of ASTM A-285 Grade C flange quality steel are important links in the modern automation chain at the General Tire plant. Built to be in operation around-the-clock under continuous pressure, the 18 pressure vessels are symbolic of the meticulous fabricating craftsmanship Graver applies to processing equipment for the petrochemical, chemical and petroleum industries. Over a century of experience qualifies Graver to tackle the most exacting specifications.

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Los Angeles • Fontana, California • San Francisco

TV process control

from page 162

both picture and sound on standard receivers where many receivers are involved.

Cost is minimum

A single camera chain may cost as little as $2,000. Extensive multi-purpose systems, of course, may cost many times as much. For maintenance, service contracts, which average 5-8% of installed cost annually, are available from most suppliers.

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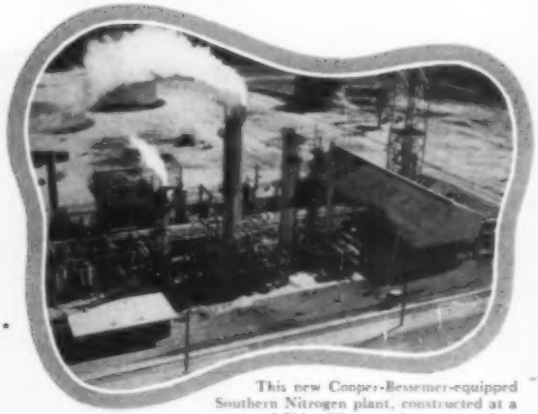
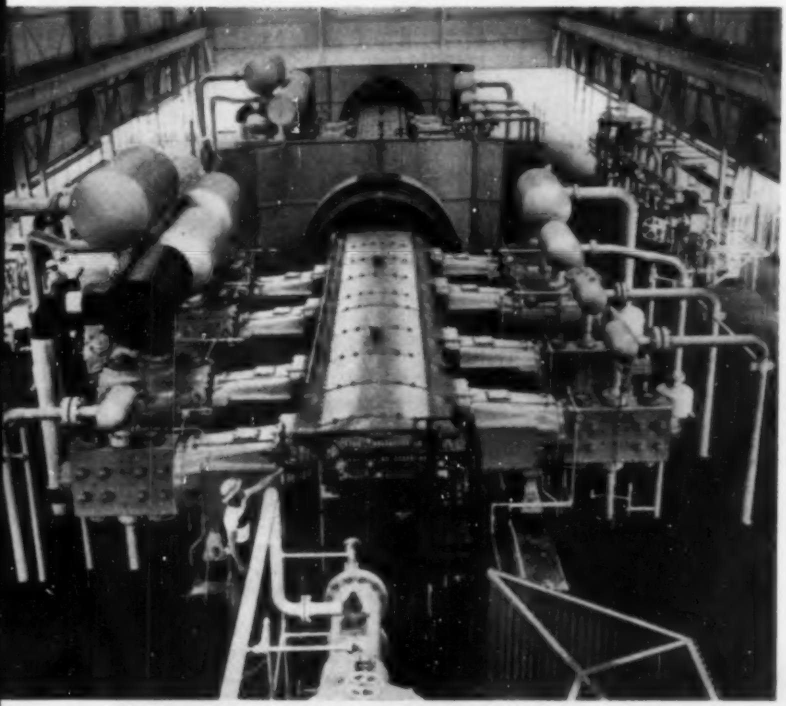
At Southern Nitrogen's huge new plant...



This new Cooper-Bessemer-equipped Southern Nitrogen plant, constructed at a cost of $14 million, produces more than 250 tons of ammonium nitrate a day.

unitized operation with only two Cooper-Bessemers handling all gas processes!



These two 8-cylinder Cooper-Bessemer LM compressors, each rated 5000 hp at 250 rpm, handle all required process work in the Savannah plant of Southern Nitrogen.

In today's modern processing plants, multiple compressing requirements are often the rule. Here is how such needs are met . . . with two automatically controlled 5000 hp Cooper-Bessemer LM compressors . . . in Southern Nitrogen Company's new synthetic ammonia plant at Savannah, Georgia.

On each LM compressor, one bank of cylinders handles compression of the gas mixture in four stages to 5125 psi. In the second bank of cylinders, one cylinder compresses pure ammonia gas, while the remaining three cylinders compress a mixture of nitrogen, hydrogen and air in three stages to 150 psi for the reforming furnace.

Cooper-Bessemer process compressors, reciprocating or centrifugal, offer the modern flexibility, extreme availability and efficiency that add up to high volume processing with minimum machinery and attendance. To be sure your files contain complete information, send for the latest bulletins.

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COMPRESSORS: RECIPROCATING AND CENTRIFUGAL, ENGINE OR MOTOR DRIVEN

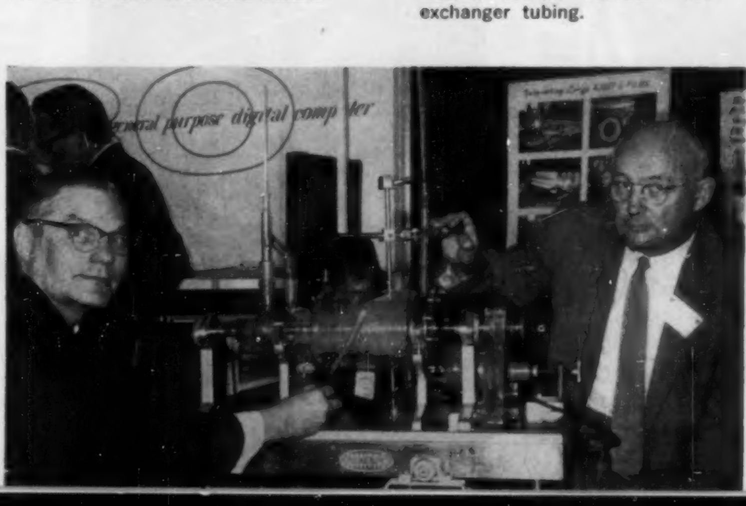
. . . . . . *at the Second National Heat Transfer Conference*

"Heat transfer highlights" luncheon was presided over by A.I.Ch.E. vice-president Donald L. Katz.

Package heating unit by Parks-Cramer used for raising temperature of oil, Arochlor, or Dowtherm to as high as 600°F., by electrical resistance heating. Pilot plant model shown has capacity of 100,000 BTU/hr., is demonstrated by L. V. Forgues.

Andrew Miller of Cardox Corp. displaying bulk liquid CO_2 storage unit feeding a vapor-chilling unit contained in a comminuting machine which reduces the size of chill-embrittled solids.

J. M. Brown, National Carbon Co., demonstrates difference in heat transfer rates between ordinary smooth wall versus new internal low-fin Karbate® heat exchanger tubing.



Transparent working model of Kontro scraped-film thermal processing machine being demonstrated by Arne R. Gudheim (l.) and Leo J. Monty. Model operated both in horizontal and vertical positions.

Feature of the "heat transfer highlights" luncheon was the summation given the audience by each table "captain" of the consensus of his table as to the outstanding heat transfer development or problem. One of the space age problems cited was that of correlating three-phase heat transfer taking place in the absence of a gravitational field.

A.I.Ch.E. had exhibit, offering both publications and membership information.

At the heat transfer banquet (above and left): Thomas H. Chilton, past-president of A.I.Ch.E. and a recent recipient of the Institute's Founders' Award, delivers an address on "Inter-society cooperation." Chilton traced the recognition of heat transfer as a basic engineering science back to 1912, and reviewed the progress up to the present joint A.I.Ch.E.-A.S.M.E. divisional activities. Compared with two other engineering sciences—fluid mechanics and thermodynamics—Chilton believes heat transfer is getting a more equitable share of "concerted and cooperative attention of appropriate groups in each of our engineering societies" Chilton further maintains that "what has been going on [cooperatively] in heat transfer points to the best way of making progress in dealing with the broader common problems of the profession." In concluding, Chilton said: "In dealing with those common problems, if we can bring to bear the devoted interest of like-minded people, we can make progress and shape organizational structure to fit the need . . . "

Richard H. Wilhelm (right), chairman of the Chemical Engineering Department at Princeton University, is the lecturer for the third E. P. Schoch Lecture Series at the University of Texas this month. Wilhelm is a national director of A.I.Ch.E. and winner of the A.I.Ch.E. Professional Progress Award (1952). Wilhelm's subject is "Reaction Kinetics and Reactor Design."

The E. P. Schoch Lecture Series, started in 1956, is supported by voluntary contributions from friends and ex-students of **E. P. Schoch** (left), long a professor of chemical engineering at the University of Texas. Schoch is now 87 years of age. The first lectures (1956) were given by W. K. Lewis on "Recent Advances in Fluidization." Second lecturer was Donald L. Katz, who spoke on "Phase Equilibria at Low and High Pressures."

California Spray-Chemical Corp. has named **Otto R. Vasak** as plant manager of its South Plainfield, N.J. facilities.

Richard Gilman Folsom becomes president of Rensselaer Polytechnic Institute. From 1933 to 1953, Folsom was associated with the University of California, where he became chairman of the mechanical engineering division.

F. P. Vance has been appointed technical assistant to the assistant manager for technical, Atomic Energy Division, Phillips Petroleum Co. Idaho Falls, Idaho.

Herman B. Goldstein, plant manager and research director of Warwick Chemical Division, Sun Chemical Corp., chairmanned the "Research Laboratory Administration" seminar of the American Management Association, held in New York last month. Goldstein has been with Sun Chemical since 1944.

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Monsanto Chemical has appointed **James L. Wallace** as technologist in the engineering department of its Plastics Division's Springfield, Mass., plant. Also at Monsanto, **David C. Hale,** joins the engineering department of the company's Inorganic Chemicals Division at St. Louis as supervising engineer in the construction section.

Paul S. Brailler, technical assistant to the president of Stauffer Chemical has retired after almost 42 years of service with the company.

Joseph E. Stepanek, former United Nations consultant, will be associated with the International Industrial Development Center at Stanford Research Institute for the next year. Prior to joining the Institute, Stepanek was consultant on industrial management to the United Nations Bureau of Economic Affairs, and had also been attached to the UN Technical Assistance Administration, for which he established technical missions in Burma and Indonesia.

R. W. Cairns has been elected a member of the Board of Trustees of the Gordon Research Conferences for a term of three years. Cairns, presently director of research Hercules Powder Co., served on the National Defense Research Committee in 1944 and 1945, and has been cited by the Navy and War Departments for his work on propellants and explosives.

The Franklin Institute's Francis J. Clamer Medal goes this year to **Julian M. Avery** in recognition of his work in inventing a method for high-pressure operation of blast furnaces.

Elias F. Joseph, formerly a development engineer at Oak Ridge National Laboratory, joins J. B. Sedberry, Inc., Tyler, Texas, manufacturers of grinding and pulverizing equipment.

Esso research and Engineering has appointed **Henry Berk** as patent associate in its patent division. Berk is a veteran of 20 years with Esso Research.

New chemical engineers at Sun Oil's Marcus Hook Research and Development Laboratory are **Edward T. Severs, Kent L. Frederick, John J. Plomer,** and **John A. Casey,** all in the product development department.

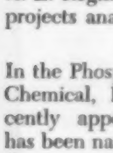
M. F. Granville, formerly superintendent at the Texas Company's Port Arthur, Texas, refinery, has been named manager of the company's Petrochemical Department in New York.

George W. Low, Jr., formerly manager of American Viscose's Fredericksburg, Va., cellophane plant, has been named manufacturing manager of the company's Film Division. Low will continue as manager of the Fredericksburg plant.

Howard L. Malakoff (left) will head a newly-organized development department at Petroleum Chemicals, Inc., New Orleans. The research division of the new department will be headed by **J. C. Kirk,** presently director of research for the company. **A. L. Regnier** will be in charge of the projects analysis division.

In the Phosphorus Division of Hooker Chemical, **Edward J. Bissaillon,** recently appointed division engineer, has been named division assistant production manager. **Barrett B. Brown,** formerly assistant production superintendent at Hooker's Niagara Falls plant, becomes technical manager for the Phosphorus Division.

Wallace P. Dunlap, Jr., is the newly-appointed production superintendent of Mobay Chemical's new Martinsville, West Virginia plant. Prior to joining Mobay, Dunlap was production superintendent of the Soda Springs, Idaho, plant of Monsanto Chemical. In his new capacity, Dunlap will replace **Richard F. Cassidy,** who becomes assistant to the plant manager of Monsanto's Krummrich Plant, Monsanto, Ill.



H. C. Mouwen has been named manager of the research and development department at Purolator Products, Inc., Rahway, N.J. He will be responsible for new product development in filtration and separation.

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people in management & technology

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S. Honari has joined the process design staff at the Richmond Laboratory of California Research Corp.

Newly-appointed members of the research department of Allied Chemical's Solvay Process Division are **Robert H. Reed** who becomes director of research, **Herbert C. Wholers,** who is named assistant director, joining the two present assistants, **Howard A. Bewick** and **E. Westley Smith,** and **Arlie P. Julien,** who becomes chief of application research.

Brigadier General Marshall Stubbs has been appointed Army Chief Chemical Officer, with the rank of Major General. He succeeds **Major General William M. Creasy.**

New assistant professors of chemical engineering at the University of Virginia are **Harold A. O'Hern,** formerly with Du Pont's Engineering Research Laboratory, and **Robert H. Moen,** formerly with the Petroleum Development Division of Esso Research and Engineering. Also at the University of Virginia, **Clarence E. Schwartz,** associate professor of chemical engineering, is on leave of absence during the academic year of 1958-1959 to serve under the International Cooperation Administration as advisor to the Seoul National University, Seoul, Korea, in helping to reorganize its chemical engineering course.

F. M. Tiller, professor of chemical engineering at the University of Houston, Houston, Texas, recently spent six weeks in Equador, where he studied the system of engineering education on behalf of the Fulbright Commission. Tiller has been made honorary professor at both the University of Quito and the University of Guayaquil.

Clarence M. Alsys and **Louis A. Salvador** have joined the staff of the Whiting Research Laboratories of Standard Oil (Indiana) where they will conduct research on improved processes for producing chemicals from petroleum.

Rolland O. Baum has been elected president of Tennessee Products & Chemical Corp. to succeed **Carl McFarlin, Sr.,** who has been made chairman of the board.

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Ciba Co., Plastics Division has appointed **William Ibsen** as assistant to the sales manager for the Structural Resins Department. Prior to joining Ciba in 1956, Ibsen was associated with the Refinery Technology Laboratory of Gulf Oil Co.

American Cyanamid Co. has named **Joseph D. Lowery** assistant sales manager of its Industrial Chemicals Division. Lowery, a veteran of 36 years with Cyanamid, was formerly manager of the company's Heavy Chemicals Department.

Malcolm B. VerNooy has been promoted to product manager in the new chemicals group of Union Carbide Chemicals Co. VerNooy will direct market development of chemicals for resin application, and the marketing of acrylates.

James C. Richards, Jr., has been named vice-president, sales, of B. F. Goodrich Industrial Products Co. Richards, who joined Goodrich in 1934, has been vice-president, sales, of B. F. Goodrich Chemical Co.

Lawrence H. Bruce has been appointed sales manager of latices for the Naugatuck Division, United States Rubber Co. Bruce joined Naugatuck Chemical in 1940 as a trainee in the production department.

Downingtown Iron Works has appointed **Charles Raysor** (top) sales engineer for Southeastern Pennsylvania, Southern New Jersey, Delaware, Maryland, North Carolina, and Virginia. At the same time, **Donald F. Baumler**, as district sales manager of Downingtown's Buffalo, New York, sales office, will handle steel and alloy plate fabrication and heat exchanger sales in New York, Ohio, West Virginia, Western Pennsylvania, Eastern Kentucky, and Tennessee.

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Tennessee Products & Chemical Corp. Nashville, Tenn., has named three new sales division managers: **E. Keith McMahon,** who becomes chemical sales division manager; **Howard B. Myers,** who will be metallurgical sales division manager; and **B. S. Howell, Jr.,** as fuels and building materials sales division manager.

Thomas R. Emblad (left), formerly of Whiting Corp.'s Chicago district office, has been transferred to the company's Pittsburgh, Pa., district office. **Melvin J. Beagle** (center), previously with

Swenson Evaporator Div. of Whiting, has been transferred to the Houston, Texas, district office. **George Kleinman** (right), formerly at Houston, will operate out of Whiting's district office at Charlotte, North Carolina.

John F. Babbitt has joined First Mississippi Corp. Jackson, Miss., as vice-president. For the past two years, Babbitt has been assistant sales manager, domestic sales, of Chemical Construction Corp., N.Y. For nine years prior to that, he had been associated with the Gas Processes Division of the Girdler Corp.

Necrology

Julian S. Pruitt, 33, chemical sales representative, Plastics and Coal Chemicals Division, Allied Chemical Corp.

L. L. Hedgepeth, 59, staff consultant, Engineering and Construction Division, American Cyanamid Co.

G. H. A. Clowes, 80, research director emeritus, Eli Lilly and Co. Clowes did important work in the development of Insulin as a treatment for diabetes.

industrial news

Expanded facilities for production of boron carbide are in full operation at the Niagara Falls, N. Y., plant of Carborundum Co. The expansion was motivated by increased use of boron carbide for control rods and shielding material in atomic power plants, and by the possibility that its semi-conducting properties will lead to significant market potential in this direction.

A $1.5 million chemical process plant has been completed at Danville, Pa. for Merck & Co. Part of Merck's new $5 million Cherokee facilities for production of ultra-high purity silicon for the electronics industry, the new plant was designed and built by Wigton-Abbott.

Full scale operation has been reached at the new-low pressure polyethylene plant of W. R. Grace at Baton Rouge, La. Shown are twin all-welded aluminum steam tube dryers, designed and manufactured by Standard Steel Corp., which are processing 5,700 lb./hr. of resin.

A new sodium chlorate plant, capacity 15,000 tons per year, is slated for completion late this year at Aberdeen, Miss. for American Potash & Chemical. While the immediate product market will be the pulp and paper industry, AP&CC envisages future production of perchlorate chemicals for high-energy fuel applications.

Ocean tanker shipment of acrylonitrile has been initiated by Monsanto Chemical. First cargo has arrived at the Coleraine, Northern Ireland, plant of Chemstrand Ltd., wholly-owned subsidiary of Chemstrand Corp.

Production of epoxidized soybean oil will start this fall in new General Mills facilities at Minneapolis, Minn. The product will be used chiefly as a plasticizing stabilizer for polyvinyl chloride resins.

Plant Construction Cost Reduction

At many recent chemical engineering meetings, leading executives have turned their attention to methods of beating the rising-cost problems in new plant construction or expansion. Here is a *CEP* roundup of some of the more important of these studies.

Modern construction methods reduce costs

Plant construction and expansion has followed the business law of supply and demand. Purchasers of engineering and contracting services have based their capital investments on marketing conditions. Present-day competition must provide, in their proposals, realistic and firm completion dates for plant construction and expansion. For this reason, the construction industry must use manpower that is trained in logic, reasoning, application of costs, and detailed planning and scheduling, in order to fulfill that obligation to their purchasers.

Technological developments in construction management is no longer the path of "craftsmanship and hard-knocks," but the path of appreciation and application of sound engineering principles. In the highly competitive field of construction, aggravated by ever rising costs due to wage increases, material escalation and shortages of skilled labor, the contractor has only one avenue of escape — *reduce costs*. This can be done by using modern construction equipment, by improving construction techniques, and by developing methods of establishing good liaison between design and construction engineers.

The development of new techniques in design, erection, and the application of equipment are, in part, prerequisites for reducing construction costs. Application of modern construction equipment lends itself to a reduction of construction costs. Periodic cost analysis, to determine measures of productivity, is a valuable aid in realigning field organizations and evaluating methods of contract execution. Contractors have found that by making slight changes in structural design, the need for heavy construction equipment to erect large pieces of refinery and chemical plant equipment has been eliminated. The study and development of designs have provided for many precast-concrete operations, permitting work to be done at ground level as opposed to being done at high elevations. The demands for skilled labor is ever becoming offset through the use of newly-developed materials and products, all contributing to the application of modern construction methods for reducing costs.

ROBERT W. HUDSON, FOSTER WHEELER CORP. *Given at Montreal National A.I.Ch.E. Mtg.*

Cost reduction in precontract planning

Engineering *before* a contract is made is essential to a sound base for the scope of work needed to fix costs with accuracy. Without this work the contractor must make an educated "guess," with contingencies added to allow for the changes in scope he knows are to come. Although this is the most important feature of precontract engineering, this engineering can produce the basis for including the latest technological thinking free from "identification." Identification is the tendency on the part of some engineers closely allied with an industry over long periods to defend the *existing* order of things. As an example; the use of this precontract engineering service enabled a \$60-million chemical plant to be built with a 12% reduction in plant cost and a 20% decrease in manpower requirements.

Contracts should be written that will not penalize a construction company for this type of thinking by fixing a definite dollar value. In another example, identification on the part of a customer's engineers nearly resulted in the severe loss of plant flexibility because the plant engineer had selected an existing location not really suited to the new addition being built. Precontract engineering revealed this and resulted in the selection of a new site.

The value of engineering for a project by both the construction company and the customer is beyond question. To put it succinctly, "Don't grasp for a doubtful dime of capital cost at the risk of losing a sure dollar of operational profit."

DITMAS BROMLEY, C. F. BRAUN. *Given before So. Cal. local section Jan. 1958.*

Types of contracts and plant costs

The field of contracts, although broad, can be narrowed for the sake of discussion by eliminating those contract situations which have less bearing on the chemical and petroleum industries. By defining a contract as an agreement to do, or not do, something, it can be stated that in concentrating on the "to do" of erecting a refinery or chemical plant means think- of a turnkey job. The work could involve a new plant or a revision of an old plant. Basic to any discussion is the fact that fundamental honesty prevails on both sides, and that both sides recognize where and how the other intends to make a profit. Contracts involve money, time, and interest on the money. Because a contractor's fee involves only a small fraction of the total money spent, very often delay in making payments can result in serious losses to the contractor.

There are many types of contracts: the straight-cost-plus; the cost-plus a fixed fee and some type of incentive; and the interim cost-plus-negotiated lump sum type of contract. The latter makes for a well-defined job. The *implied* (or quasi) contract has many pitfalls. It does not provide for changes in scope, or insurance. Arbitrary insurance clauses can result in needlessly increasing the cost of small projects in large plants, and can

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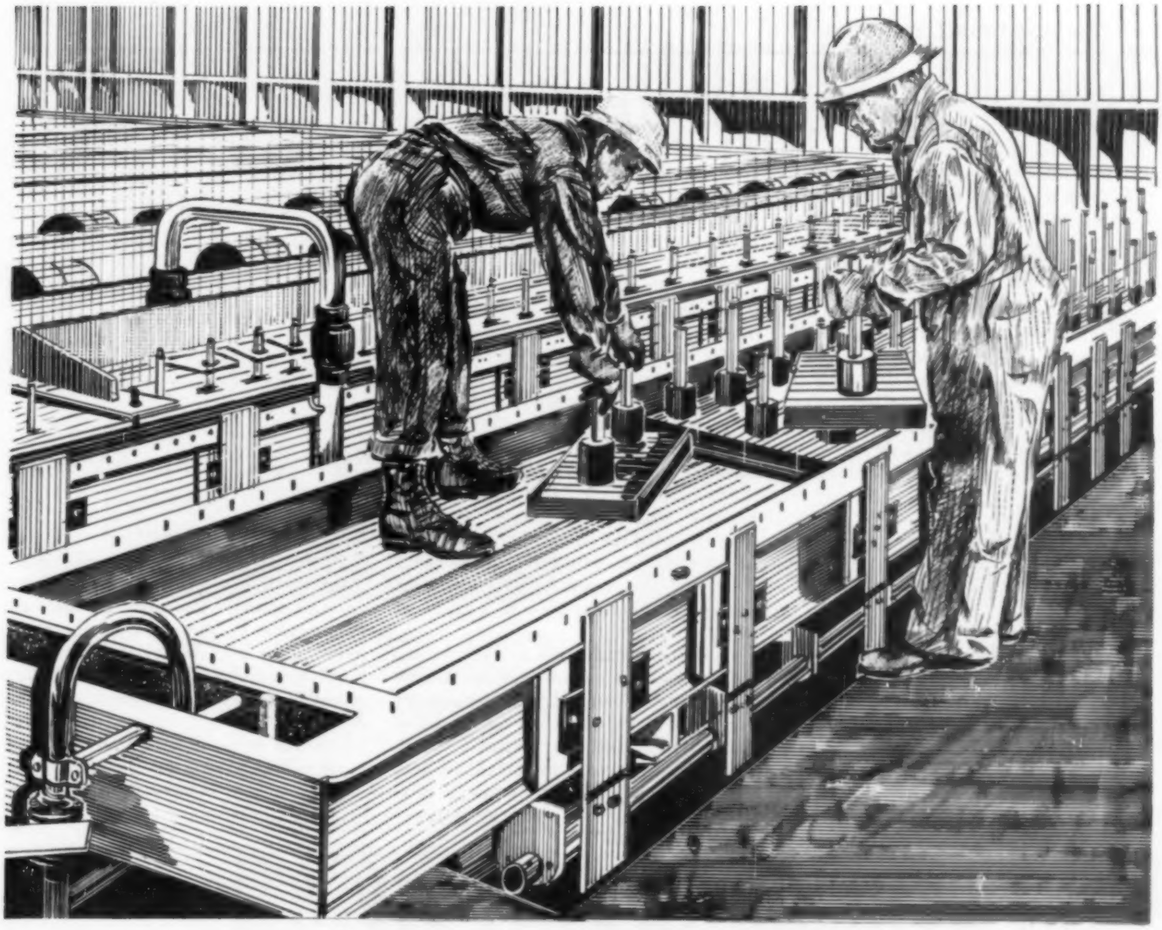

double and triple protection costs on larger jobs.

Mechanical guarantees on equipment should be limited to the length of time specified by the vendor; as should workmanship guarantees. Process guarantees are a special consideration and should be evaluated carefully. As to job completion, this is important to define, and final payment, except for guarantees, should be just that—final! Both client and contractor should realize that their relations are on a more or less repeat basis. Both sides ultimately establish a reputation of fairness or weakness and learn to protect themselves accordingly.

George Ehrhart, Ehrhart Assoc.
Presented at So. Cal. local section meeting, Jan. 1958.

Cost reduction in engineering construction

Getting down to cases in reducing the costs in the engineering and construction of a new plant, the most important cost reduction is to put a competent team in the field; a team aware of the objectives, urgency, and cost, and to let them develop a plan that is challenging with respect to time and money. The application of good engineering know-how is essential. Specifications should be functional.

Although we know that the usual good design practice calls for a safety factor of four to five for piling under major structures, this can be wasteful in some cases where 1.5, or even 1.2 would suffice. Another wasteful practice is to call for indiscriminate valving to provide for "every remote possibility". Some "standard specifications" which have been expanded to include every contingency, cause a contractor to do such ridiculous things as provide for winterizing in a plant built in the tropics, or to protect against salt air corrosion in a midwest location.

Advanced tools such as digital computers and the use of models can provide more efficient plant designs faster and at a lower cost than the so-called "short-cut" methods formerly used. Good job control is important to both the contractor and the owner's project engineer, himself. Resistance on the part of the owner to changes after the plant designs are well along can provide dividends in money saved. To be well done, a job must be well conceived, well planned, well scheduled, and well controlled. These things do not come about accidentally, but should be given thought by the very best talent available for the job intended.

John Marshall, Fluor Corp.
Presented at the So. Cal. local section meeting, Jan. 1958.

Cost reduction in new plant construction

It should be pointed out that the engineering and design of a chemical plant by a construction company in no way changes the need for careful engineering on the part of the customer. The best design of a chemical plant can only be based on a customer's firmly engineered scope. Troublesome plant designs can occur when this scope is lacking. The principle reason behind the prevalent con-

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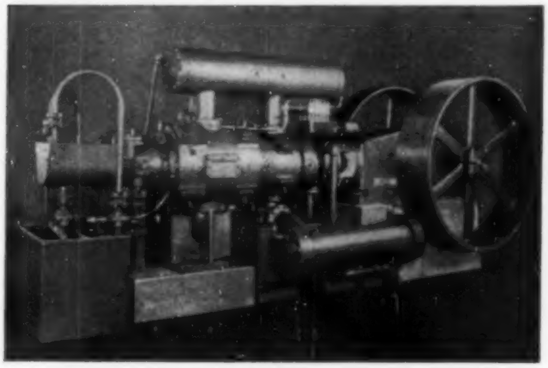

The five stages on this heavy-duty tandem compressor require less horsepower and develop less heat than in four stages in producing 3000 lb. per square inch pressure in capacities up to 31,000 cfh.

Frames with double row roller bearings, reversible ring plate valves, force feed lubrication, generous intercooler coils are some of the features that make this horizontal compressor compact, sturdy and efficient to operate and maintain.

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Norwalk makes compressors from single stage to six stages, from 125 to 25,000 lb. psi. Catalog on request.

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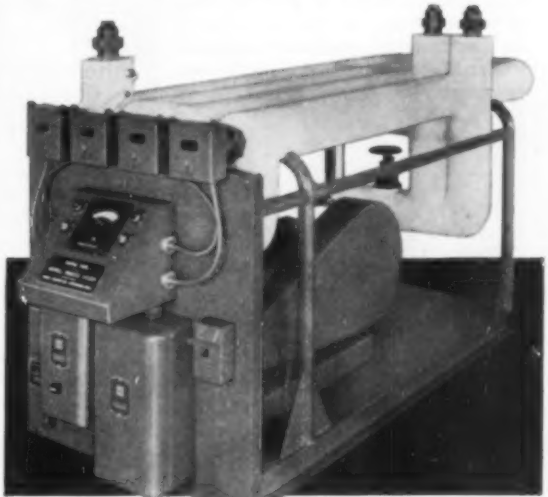

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Tyler award to Othmer

The Stephen L. Tyler award of the New York section was given to Donald F. Othmer of Brooklyn Polytechnical Institute in recognition of the "Encyclopedia of Chemical Technology" which he co-edited with the late Dean Raymond E. Kirk, of the same school. The Tyler Award is given each year in honor of Dr. Tyler, a past Secretary of the Institute, to the author(s) of the most notable contribution to chemical engineering literature in the year.

Steve Tyler (left) confers award named after him to 1958 winner Othmer.

On the same New York program, Ralph Landau enumerated some 30 "inventions" marketed by the Chemical Process Industries since World War II as the reasons for the growth of the industry. The Executive V. P. of Scientific Design, in a critical assessment of scientist-management relations, demonstrated that our scientist-engineers are not sufficiently represented in top management.

Scholarships, Nasser among local section topics this month

Why do certain high schools in the U.S. consistently graduate large numbers of scholarship winning students? This was the question R. F. Marschner of Standard Oil of Indiana tried to answer at a recent **Central Ohio** (*J. H. Oxley*) section meeting. In his capacity as president of an Illinois high school district Board of Education, Marschner had the opportunity to survey 38 high schools throughout the country which produced the largest number of National Merit Scholarship finalists. The answer he presented was complex, involving many factors, each of which he explained.

Some of the conclusions he cited included: the types of communities in which the schools are located (more than half of the schools are in suburban areas); the caliber of the pupils assigned to the schools (most of the schools had students with ability levels well above the country-wide average); the teachers sought out and employed; the emphasis the schools placed upon the scholarships. In almost all cases the standards were uncompromisingly high. These are exemplified by such statements as "We started high, and raised our standards from year to year," "We simply refuse to accept mediocrity." These are strong words, but in them probably lies the secret of success of any school, and the basis on which the country's future greatness is built.

The crisis in the mid-east will not lead to war. While the average Arab does not quite grasp what its all about, he feels that any change will be an improvement, so long as there appear

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to be changes for the better in the offing, he enthusiastically supports the so-called nationalistic movement. These views were expressed by Rear Admiral Angus Sinclair, Pres. of the Middle East Institute, before the August meeting of the **National Capital Section** (*J. L. Gillman*). He explained that Nasser is a sincere and popular leader, as well as a dynamic master of propaganda.

While Nasser's aim is to create a strong Arabic nation, Sinclair feels that, because of conditions peculiar to each nation, the result will be a rather weak federation; akin to the British Commonwealth. Of importance to the U.S. is Sinclair's feeling that Nasser's greatest enemy is Russia! Russia, he feels, has every reason not to want a strong independent nation to be created in the mid-east. Knowing this, Nasser makes the most of the east-west animosity by playing one side against the other.

The great need of most Arabic nations, Sinclair stated, is money and skill. The money could come from the Persian Gulf states of Kuwait, Bahrein, and Qatar, the skills must be acquired over a period of time.

Also meeting

Tracing their history from the earliest records found in the tombs of Egyptian kings up to their use in the 20th century, O. L. Morton of Shulton, described Toiletries, Cosmetics and Perfumes for the special Ladies Night of the **New Jersey** section *(R. J. Boyle)* which was handled by the wives of the section officers. The **Pittsburgh Section** *(V. N. Hurd)* listened in April to James B. Weaver of Atlas Powder on Economic Evaluation. In May, the section heard Harry I. Thompson, Jr. of the John L. Dore Co. discuss uses of Teflon in the chemical process industries . . . . The contribution of the individual to the development of professionalism was the theme of vice-president Donald L. Katz at the June meeting of the **Rocky Mountain Section** *(Fred H. Poettmann)* . . . . Spray drying, pneumatic drying, fluidized bed drying featured a talk on "New Trends in Drying Processes" by W. R. Marshall of the University of Wisconsin at the January meeting of the **Rochester Section.** February found the **Rochester** members listening to O. E. Dwyer of Brookhaven as he discussed "Chemical Engineering and the Liquid Metal Fuel Reactor." . . . Solu-

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PROCESS ENGINEER—Seventeen years' experience in economic analyses, long range planning, process development, process design, and initial operation of petroleum chemical plants and oil refineries. Responsible charge of projects for engineering contractor and supervisory experience over plant engineering department for operating company. Desire position in operating company, either in engineering or production. Box 5-10.

PRODUCTION MANAGEMENT ENGINEERING—Age 44, Ch.Eng., B.S. Seventeen years in chemical industry. Plant superintendent in petro-chemicals, familiar with process engineering, production, corrosion problems, and maintenance of chemical plants. Seeking position in production management. Box 6-10.

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CHEMICAL ENGINEER—B.Ch.E., 1942. Sixteen years' experience in operations, economic studies, standards, cost reduction programs and various industrial engineering functions. Several patents. Oil, steel and chemical background. Box 8-10.

CHEMICAL ENGINEER—Age 30, family. Seven years' production control and improvement, including four years' economics, scheduling ops., petroleum solvent refining. Desire responsible position in production control and process improvement. Box 9-10.

SUPERVISORY CHEMICAL ENGINEER — B.Ch.E. Age 31, married, veteran. Eight years' process and product development experience. Desire position where ability to get along well with people is important. Present position, section head; present salary, $9,600. Will relocate. Box 10-10.

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Did You Know . . .

. . . that the first chemical engineer in the atomic energy field was Marie Curie . . . that Iceland expects to supply most of the power for her developing industry from geothermal wells . . . that David Wesson, the discoverer of the vacuum-deodorizing of cottonseed oil, was a founder of the A.I.Che.E. . . . that chemical engineering has recovered more than 50 per cent of the value of coal used for coking . . . that the ancient Egyptians used filter presses . . . that the A.I.Ch.E. was the first engineering society to accredit college curricula . . . ?

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The Situations Wanted portion of this Classified Section is preprinted and mailed a few days in advance of publication, to Employment Directors. Send names of individuals who should be on mailing list to: Miss E. Adelhardt, Chemical Engineering Progress, 25 W. 45th Street, New York 36, New York.

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Every so often an unprecedented demand for a particular issue, or an unexpected influx of new subscribers and members puts the editor in the embarrassing position of running out of copies of Chemical Engineering Progress. This has happened several times in our short history and if members have copies of any of the following issues, we would be glad to purchase them.

The issues which we need and for which we will pay 75 cents each are: January, February 1958.

All these issues were overprinted to the usual extent, but because popular features spurred single copy sales, our reserves are exhausted.

Help fellow members by sending your back numbers of the issues specified above to:

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local sections

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tion of chemical engineering problems on actual operating analog equipment featured the presentation of Charles W. Worley of Electronic Associates before the **Southern California Section** *(Henry C. Meiners)* in April. His subject: "Applications of the Analog Computer to Chemical Engineering Problems . . . . A jointly-sponsored meeting of the **Southwest Louisiana Section** *(J. M. Anderson)* and the Lake Charles Chemical Engineers.

The annual joint meeting of the **Western Massachusetts Section** *(R. E. Delacretaz)* and the **Student Chapter of the University of Massachusetts** in March heard George W. Bain, professor of Geology at Amherst College on "Sculpturing of the Connecticut Valley". Nothing to worry about in the near future, said Bain, the period of great earth movement is ending, future changes in the Connecticut Valley will amount to gradual reduction of elevation by forces of erosion.

Cost reduction

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struction of plants on a turnkey basis is the high cost of delays where engineering and construction are done by separate companies, rather than concurrently by the same company. The complexity of the modern chemical plant, and the difficulty of fixing responsibility are also reasons.

The major risks in chemical plant construction are: inadequate scope; getting into the field too early; and job acceptance delayed beyond vendor's guarantees.

FESS C. BURKS, RALPH M. PARSONS Co. *Panel on cost reduction in chemical plant construction; Southern California section A.I.Ch.E., Jan. 1958, (Loren N. Miller).*

Specialized semiconductor components will be manufactured by the Shockley Transistor Corp., newly-formed subsidiary of Beckman Instruments. Formation of the new company, says Beckman, follows a two-year development and pilot production program directed by William Shockley, Nobel prize winner and inventor of the junction transistor.

Atlas Powder will consolidate all its Eastern explosives production at its Reynolds plant, near Tamaqua, Pa., will discontinue production at its White Haven, Pa., plant.

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news and notes of A.I.Ch.E.

New Local Sections—The Executive Committee at its most recent meeting voted to approve the formation of the Central Illinois Section with headquarters in Tuscola, Illinois and the establishment of the North Jersey Section with headquarters in Nutley, New Jersey. The chairmen of these groups are G. E. Montes and O. S. Knight respectively.

Engineering Societies Monographs—A.I.Ch.E., now that it is a founder member of the United Engineering Trustees, also becomes associated with the Engineering Societies Monographs. This series of 14 books is outstanding in the engineering profession. Recently the Executive Committee studied the contract in force between U.E.T. and the McGraw Hill Book Company, which publishes the series, and there being no objection to it, studies are now underway to select committeemen to represent us.

Appointed to represent A.I.Ch.E. on the Library Board of U.E.T. were N. W. Krase of Du Pont and R. P. Smith of the National Lead Company.

Tellers Committee—Soon the ballots will be forwarded from the Secretary's office to all Members and Associate Members of A.I.Ch.E. to vote on the list of candidates shown on page 114 of the August issue. This year an I.B.M. card will be used as the ballot, procedure being much the same in regard to signing the outer envelope, etc. However, we intend to use the returned card to punch and tabulate the vote directly—so please don't mutilate it in any way. The President recommended to the Executive Committee that the Tellers Committee be M. Strawn, J. W. Colton, J. W. Axelson, and R. J. Bechtel.

Member Giving—Theoretically by now every member of the Institute has received a call about his contribution to the United Engineering Center to be built in New York. None of this should be news to our members for we have featured it in practically every issue of C.E.P. this year (see August and September issues in particular). We have distributed to all the campaign chairmen pamphlets on the U.E.T., its history and high lights as told by W. J. Barrett, President, A.I.E.E. and the U.E.T. It is a rather interesting personal history and should any member desire a copy we shall be glad to send one.

One phase of the Member-Giving Campaign should be of great interest to those being asked to give now. As a result of the special campaign headed by Sid Kirkpatrick and Walter Whitman, about 200 chemical engineers have contributed about $78,000, or 26% of the total we must raise. It is now up to the 99% of the membership to raise the 74% needed to make our quota—surely the chemical engineers can do this and it is the hope of those concerned with the campaign that, as the newest members of U.E.T., the chemical engineers go well over their quota to assert their deep interest in this project.

Membership—We have not reported for several months now on the contest between the Southern Division and the Northern Division but, if the Southern Division is going to catch up to the Yankees up north, a few more northern states are going to have to secede. Sam West's group of local sections was well in the lead over Irv Leibson's southern group and Irv, to show his embarrassment, has sent his August report to the local sections representatives on red paper. Outstanding in the Northern Division have been: J. E. Frank for the Chicago Section, L. L. Saphier for Midland, R. I. Bergman for New Jersey, Joel Henry for New York, D. E. Abercrombie for Philadelphia-Wilmington, and K. H. Slagle for Pittsburgh. The leaders for the southern contingent have been H. F. Kraemer of Baton Rouge, J. M. Kunkel of Southern California, W. J. Burkett of South Texas, and L. F. Brennecke of St. Louis.

Special Project—The Program Committee is planning a distinct innovation for the Cincinnati meeting in December. Under the guidance of Gene Smoley, Hugh Guthrie, and R. R. White, a special lecture with limited attendance on a "first come, first served" basis and with a special registration fee will be held on Saturday, December 6. This will be an all-day special investigation on "New Ideas in Turbulence" with Stanley Corrsin of John Hopkins University as the principal lecturer . . . supporting lecturers will be T. Baron of Shell Development Company and H. M. Hulbert of American Cyanamid Company. Preregistration will be required for this special day's program and it is our hope to have notices of the lecture in the mail by the time you read this. It is planned that the audience be limited to 100 persons, and should requests exceed this number, there will be an attempt to limit the attendance to one person from a company, or else to repeat the lecture at a future meeting. Behind this addition to the program is a feeling that there is a need to explore deeply subjects in chemical engineering which have made recent noteworthy gains. Should this prove to be a success, it will be repeated with specialized subjects at other meetings. It is intended that these sessions will provide advanced ideas to those who are already knowledgeable in the field, rather than an elementary appreciation to those not having the necessary background. The registration fee will probably be substantial compared with the registration fees of Institute meetings in general, owing to the need to make this self-supporting.

Student Chapter Counselors appointed since July, 1957, are as follows: R. M. Boarts for University of Tennessee, W. W. Bowden for Rose Polytechnic Institute, J. M. Church for Columbia, Joshua Dranoff for Northwestern, R. W. Fahien for Iowa State, C. J. Huang for University of Houston, Harvey L. List for City College of New York, Robert Luedeking for Washington State, G. W. Minard for Bucknell, Robert O. Parker for New York University, John M. Prausnitz for University of California, and Robert L. Steinberger for Cooper Union.

F.J.V.A.